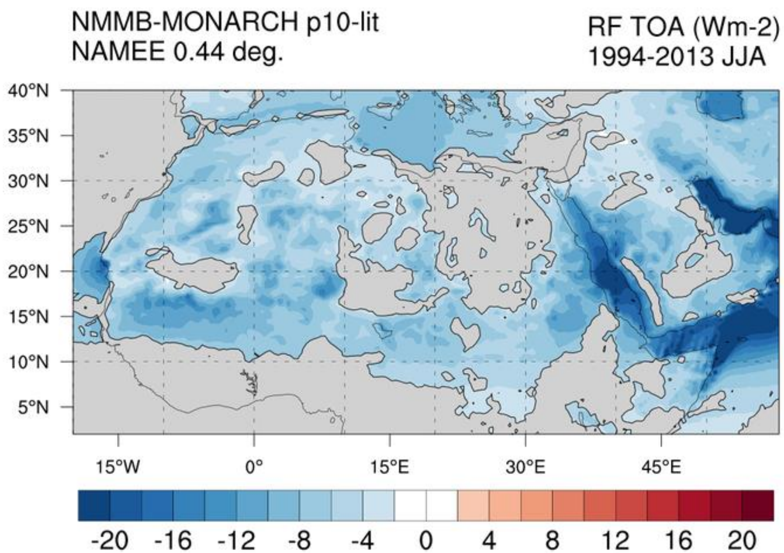
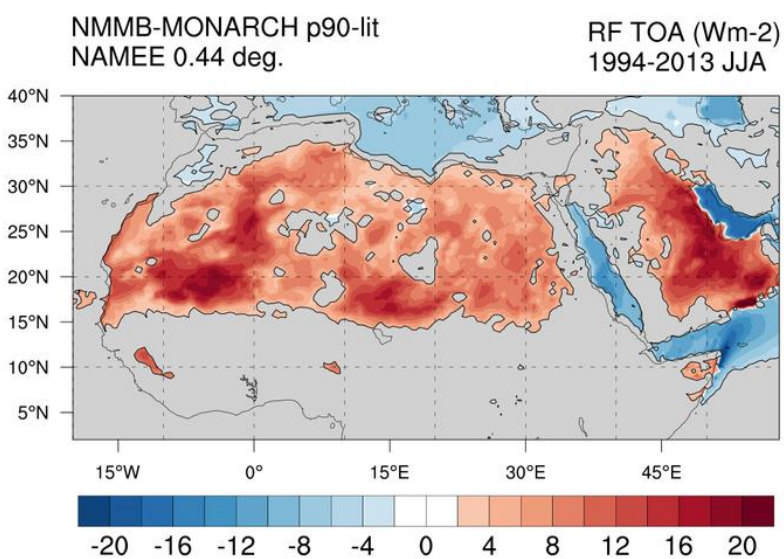
# Climate response to soil dust aerosol and its sensitivity to mineralogical composition in Northern Africa

M. Gonçalves-Ageitos, V. Obiso, O. Jorba and C. Pérez García-Pando




**Dust single scattering albedo**

↑ Imaginary part of the refractive index

<u>Dust mineralogical composition</u>

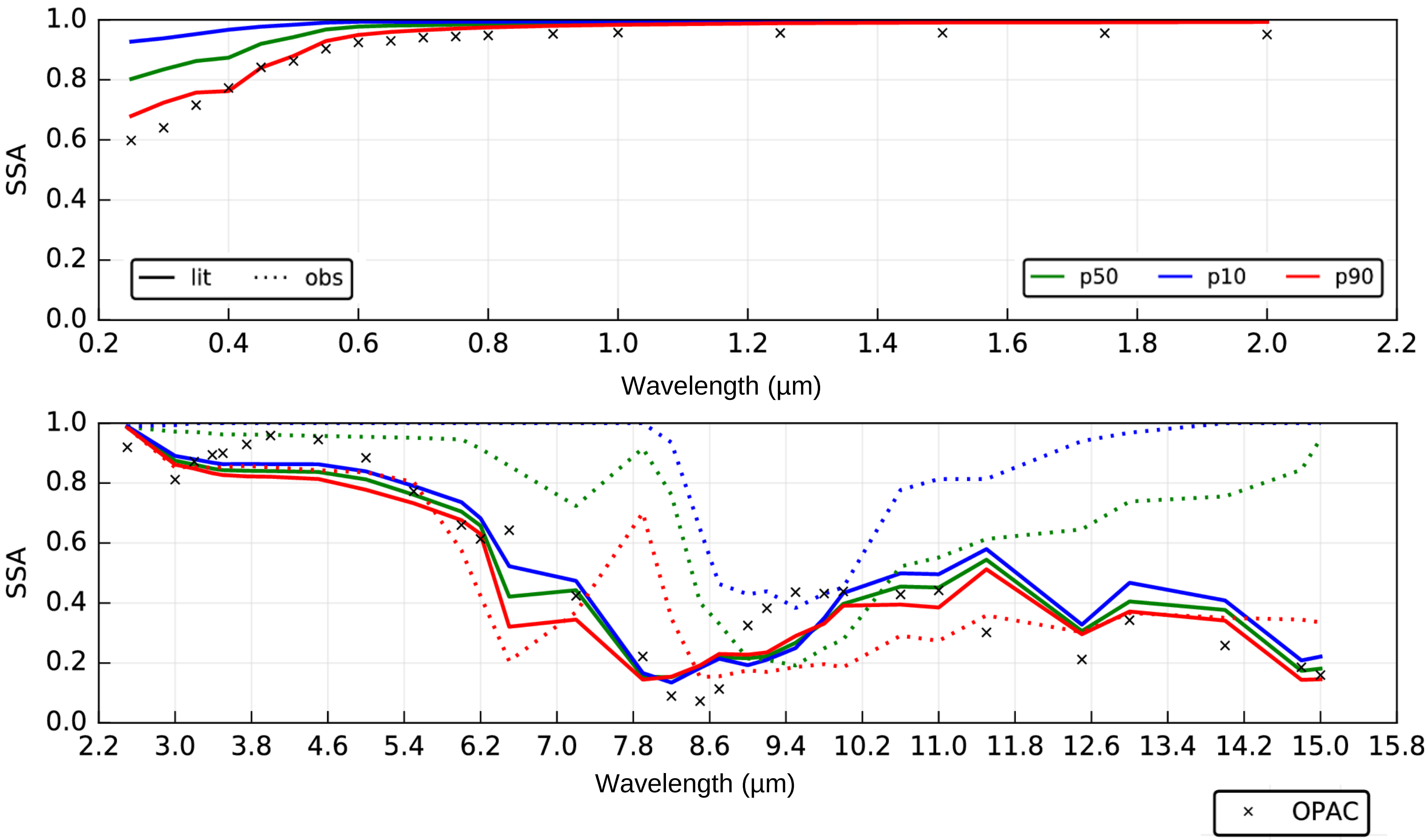
- <u>Soil mineralogy content</u> (Claquin et al. 1999)
- <u>Literature</u> reported <u>refractive indexes</u> (Scanza et al., 2015; ARIA-Oxford database)
- Measurements from <u>chamber</u> (Di Biagio, 2017)

Barcelona Supercomputing Center
Centro Nacional de Supercomputación
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Climate response to soil dust aerosol and its sensitivity to mineralogical composition in Northern Africa

EGU2019-15036

M. Gonçalves-Ageitos, V. Obiso, O. Jorba and C. Pérez García-Pando




Screen 5.a14

Special thanks to: C. Di Biagio, P. Formenti, M. Schulz, the AERONET and ECMWF data providers, and the Oxford University for the ARIA database. This work has been developed in the framework of the FRAGMENT ERC, the AXA Chair on SDS and all simulations were run in the Marenostrum4 supercomputer (BSC-CNS).

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

mailto:
maria.goncalves@bsc.es

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Climate response to soil dust aerosol and its sensitivity to mineralogical composition in Northern Africa

EGU2019-15036

M. Gonçalves-Ageitos, V. Obiso, O. Jorba and C. Pérez García-Pando

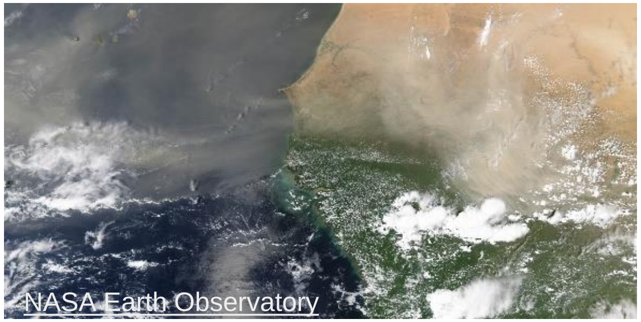


Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Aim

- To assess the impact on climate responses over North Africa of changes in the imaginary part of the dust refractive index constrained by its mineralogical composition



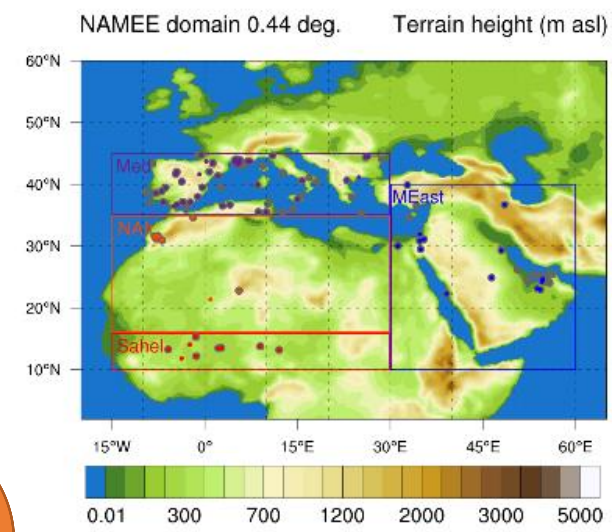
(Aqua-MODIS image by J. Allen)

- Scientific questions:
  - Can we reproduce observed optical properties for dust deriving them from our best knowledge of its mineralogical composition and mineral-dependent refractive indexes?
  - Is the response on North African climate features sensitive to those mineralogy constrained changes in dust optical properties?
  - Are the effects on the SW and LW equally relevant?

# Methodology in a nutshell

NMMB-MONARCH as regional climate model
20-year long runs for the NAMEE region

RRTM for LW and SW radiation
Coupled with dust online (GOCART clim. for other aerosols)




Dust single scattering albedo

## Scenarios:

- We perturb the **imaginary part of the refractive index for dust:**
  - 2 scenarios based on literature refractive indexes and mineralogical composition of dust (derived from that of the parent soil)
  - p10-lit (*sca*), p50-lit (*med*), p90-lit (*abs*)
  - 3 scenarios derived from those, modifying the LW refractive indexes to match recent chamber measurements (Di Biagio et al., 2017)
  - p10-adjlw, p50-adjlw, p90-adjlw
- Reference simulation without aerosol radiation interaction (NA)

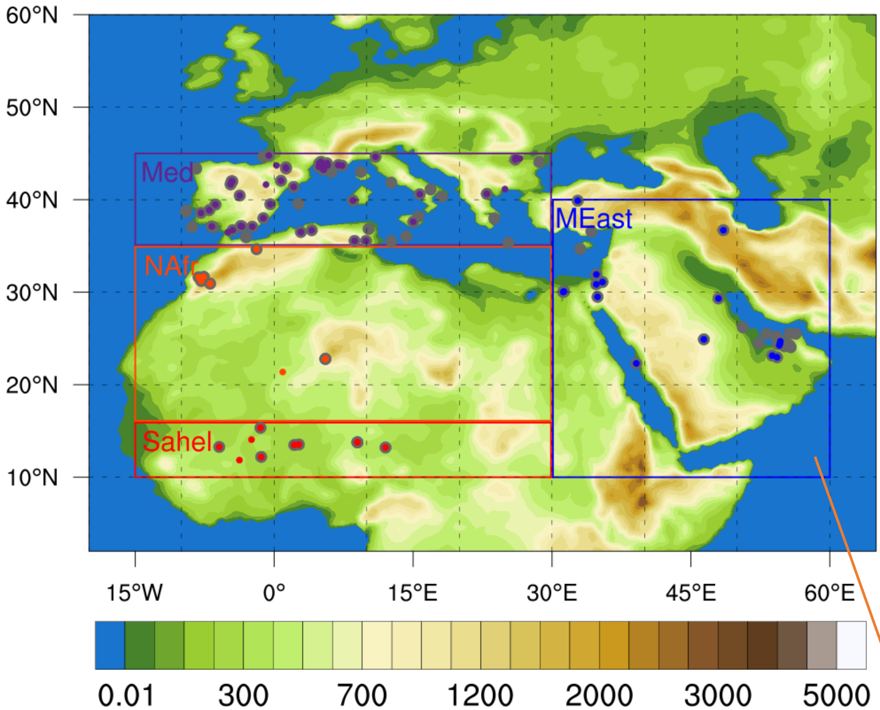
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Domain and model setup

Multiscale Online Non-hydrostatic AtmospheRe CHemistry model (NMMB-MONARCH)

NAMEE domain 0.44 deg. Terrain height (m asl)




- Center at 35ºN-20ºE
- 232x160 cells of 0.44º of horizontal resolution.
- 40 vertical layers up to the top of the atmosphere (set at 50 hPa)

**Model configuration:**

- 20-year long simulations
- ERA-Interim for boundary conditions and sea surface temperature
- Schemes:
  - RRTM for SW and LW radiation
  - Betts-Miller-Janjic scheme for convection
  - Ferrier microphysics
  - Mellor-Yamada-Janjic turbulence
  - Noah land surface model
- Online coupling of LW and SW radiation with mineral dust
- GOCART climatology for other aerosols

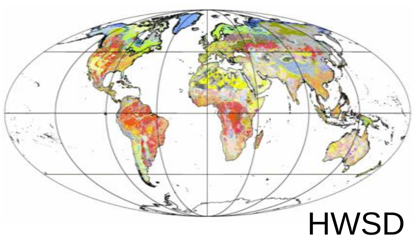
Subdomains defined for model evaluation against AERONET data

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

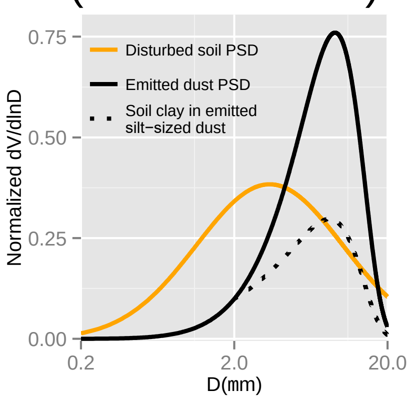
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Scenarios definition

Soil mineralogy atlas (Claquin et al. 1999)




Emitted size distribution (Kok et al. 2011)




Perlwitz et al., 2015a,b
Pérez García-Pando et al., 2016
Pérez García-Pando et al., in prep

Mineral fractions in airborne dust from each soil type

Refractive indexes per mineral (Scanza et al., 2015; Oxford Univ. - ARIA dataset)

Internal mixtures per dust size bin

Maxwell Garnett method (Markell 2016)

Range of variability of the refractive indexes for dust

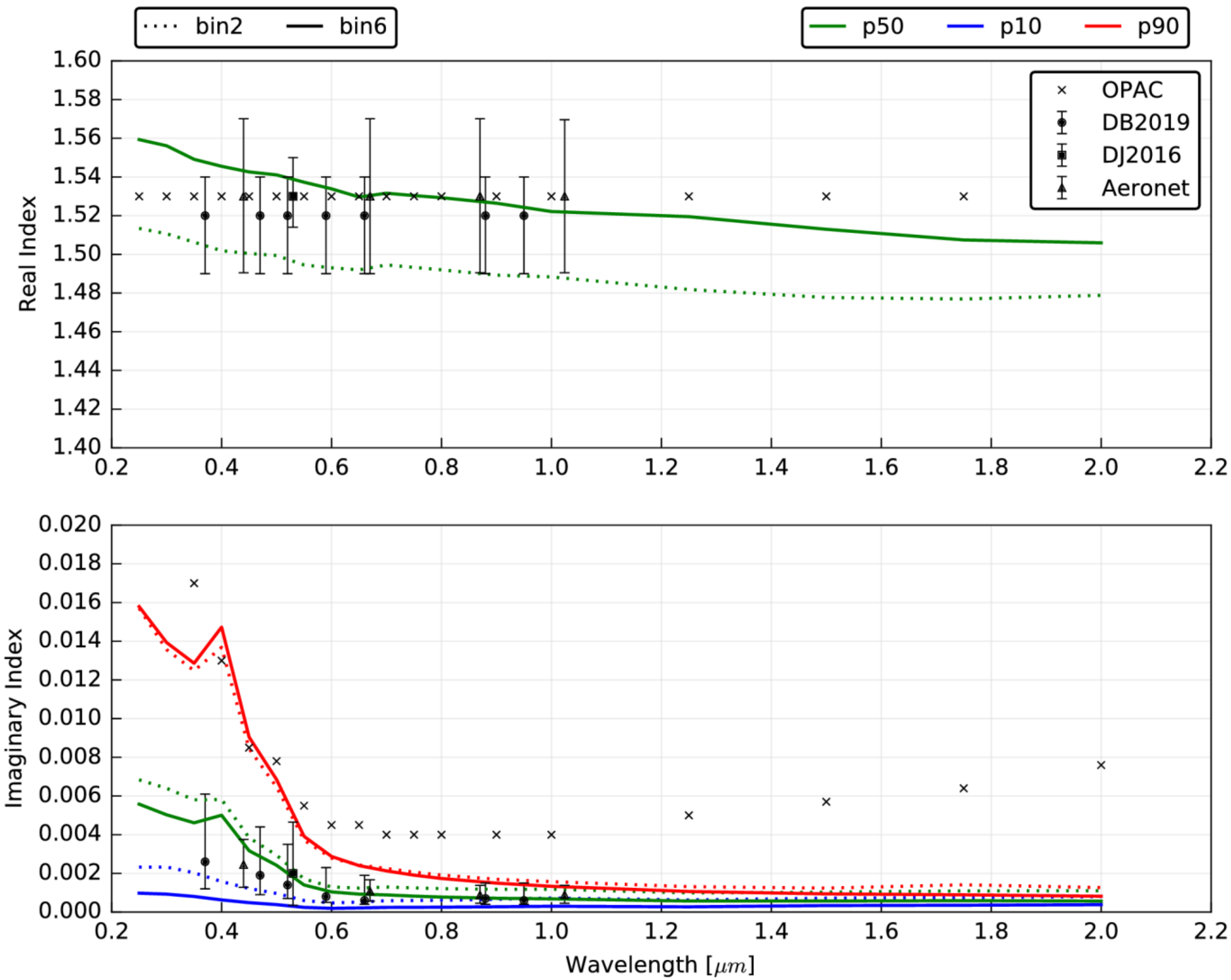
**SW**

**LW**

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Scenarios: Refractive indexes for dust (SW)



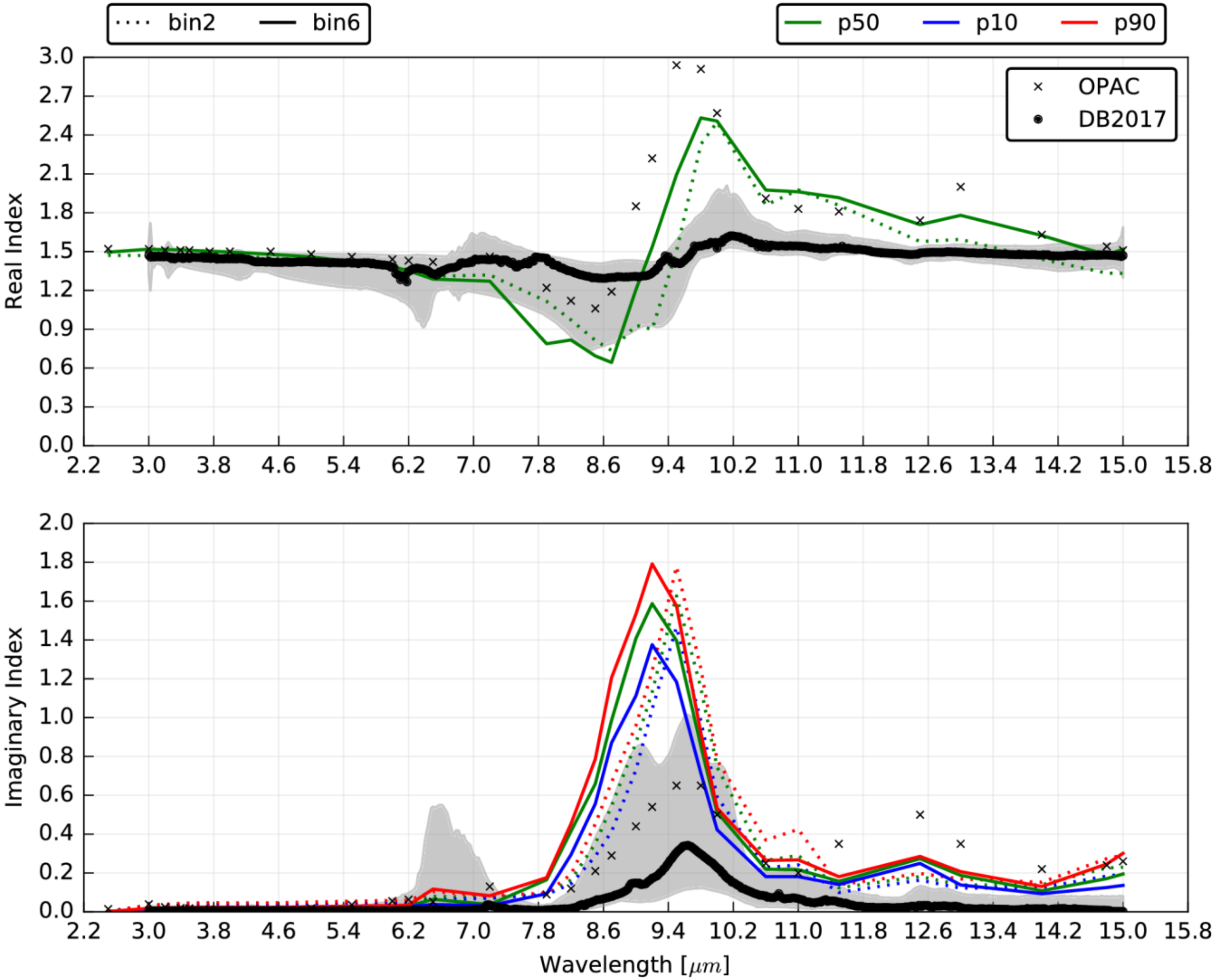

The imaginary part of the RI falls within the observed ranges for the median and the more scattering scenarios (p50, p10)

p90 shows a quite absorbing feature in the hematite dominated bands (~0.25 to 0.6 μm)

bin2 (r 0.18 - 0.3 μm)
bin6 (r 1.8 - 3.0 μm)

AERONET: Balkanski et al. (2007)
DB2019: DiBiagio et al. (2019) in review
OPAC: Hess et al. (1998)
DJ2016: Denjean et al. (2016)

# Scenarios: Refractive indexes for dust (LW)




The imaginary part of the RI shows more absorbing features than the chamber experiments (DB2017) or OPAC indexes for all our scenarios using literature retrieved indexes.

bin2 (r 0.18 - 0.3 µm)
bin6 (r 1.8 - 3.0 µm)

DB2017: DiBiagio et al. (2017)
OPAC: Hess et al. (1998)

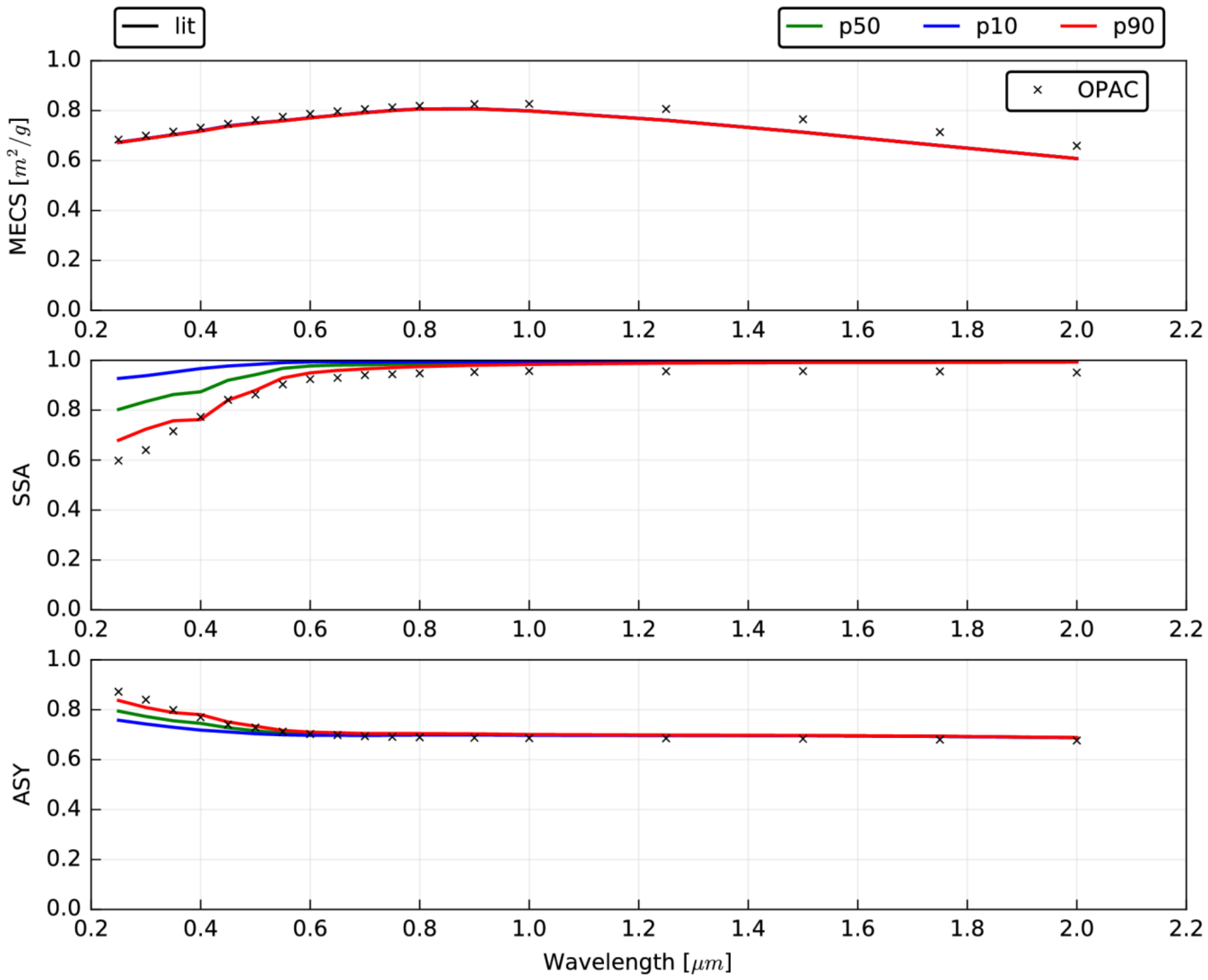
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Go to optical properties eval.

Go to climate responses

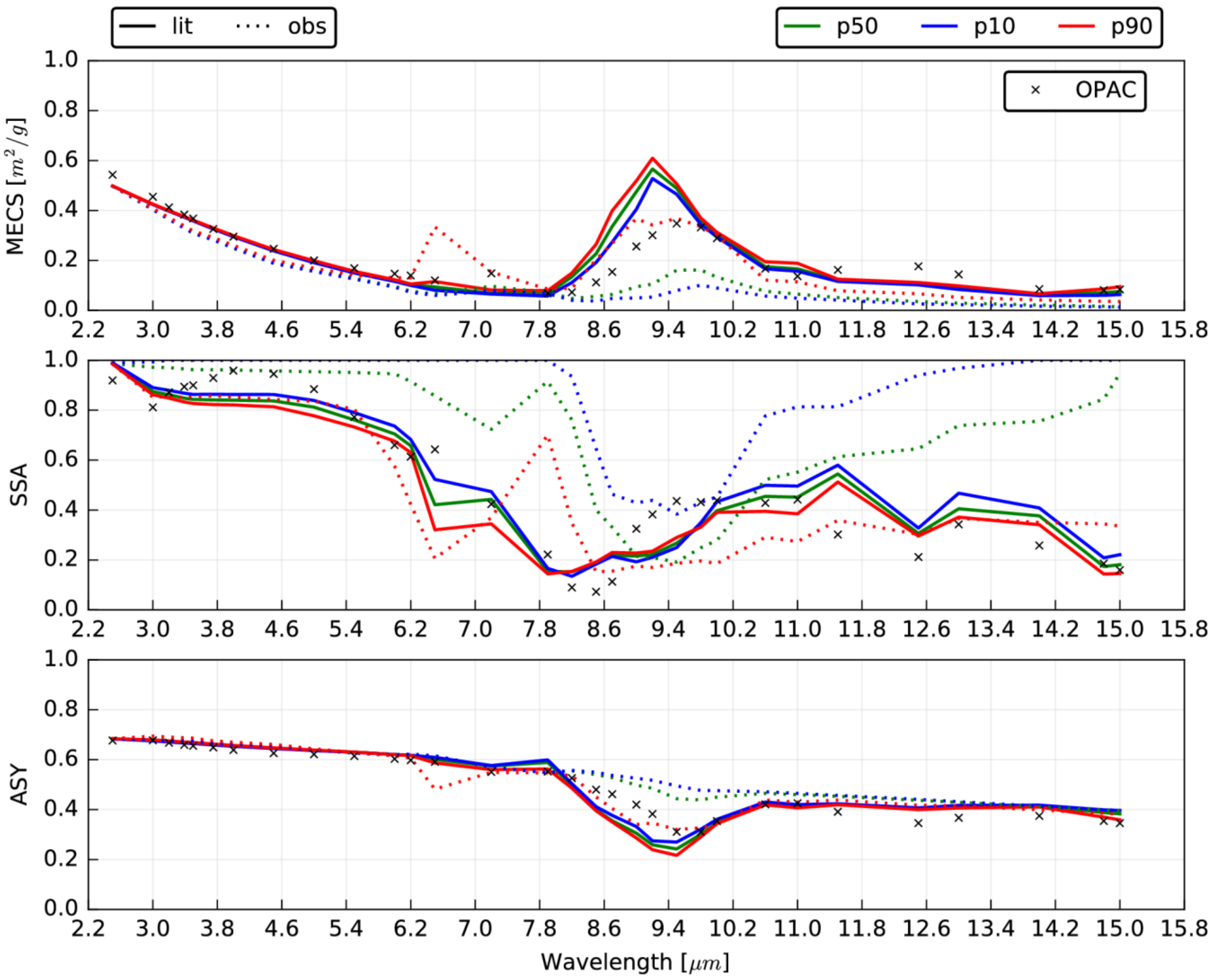
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Sample of the changes in dust optical properties (SW)



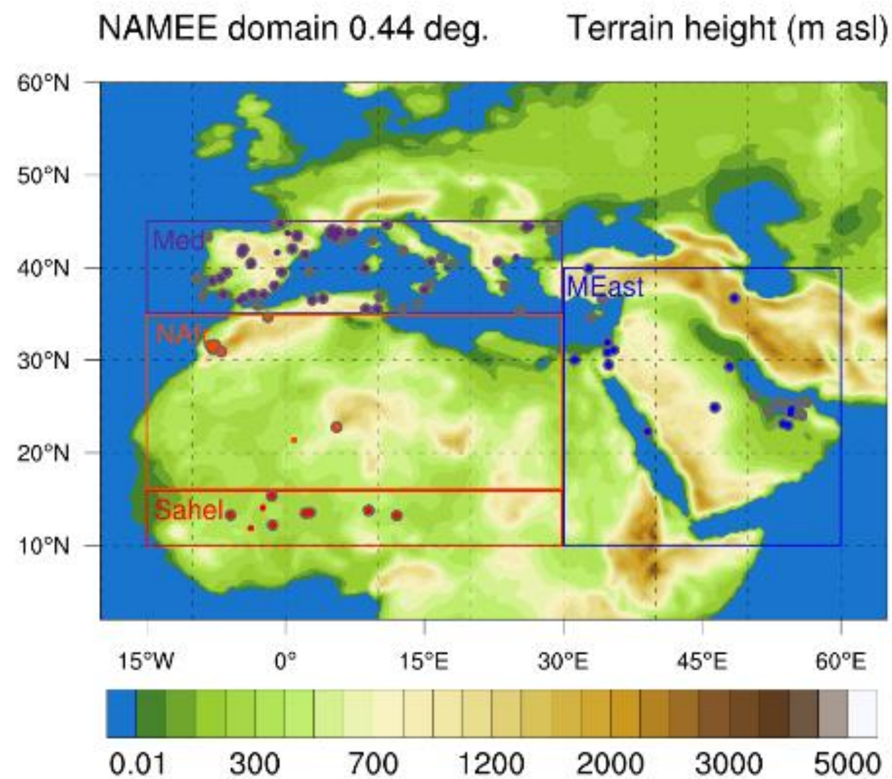

Mass extinction coefficient ($m^2/g$), single scattering albedo and asymmetry factor parameters, calculated for a dust mass size distribution representative of long-range transport.

# Sample of the changes in dust optical properties (LW)




Mass extinction coefficient ($m^2/g$), single scattering albedo and asymmetry factor parameters, calculated for a dust mass size distribution representative of long-range transport.

# Evaluation of DOD@550nm and SSA@550nm against AERONET data




Stations used for

- DOD: colored dots
- SSA: grey-shaded dots

## Evaluation of dust optical depth

Coarse AOD climatology from AERONET:

- Level 2.0 quality assured daily retrievals
- AOD@440 nm, Angstrom exponent 440-870 nm
- Coarse AOD filtered by Ae<0.75
- Monthly means only when 20 days of data are available

## Evaluation of single scattering albedo

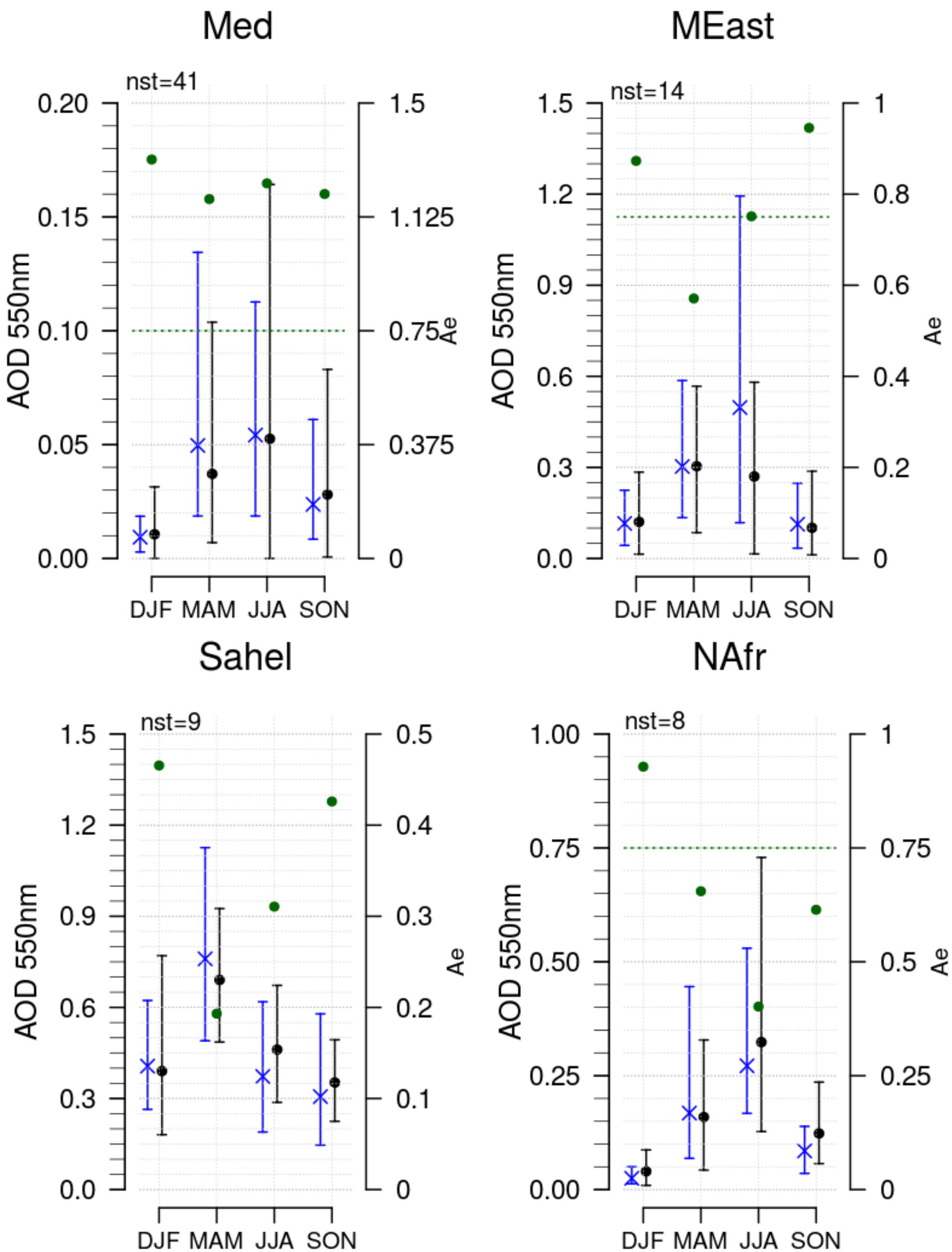
SSA climatology from AERONET:

- Level 1.5 data, manually screened to meet all level 2.0 criteria (except AOD@440 nm > 0.4)
- Monthly means only when 20 days of data are available

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

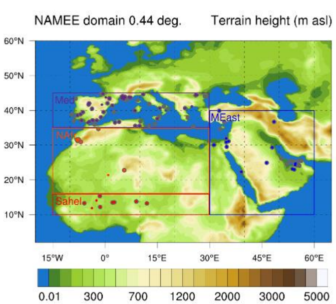
# Evaluation of DOD@550nm against AERONET data



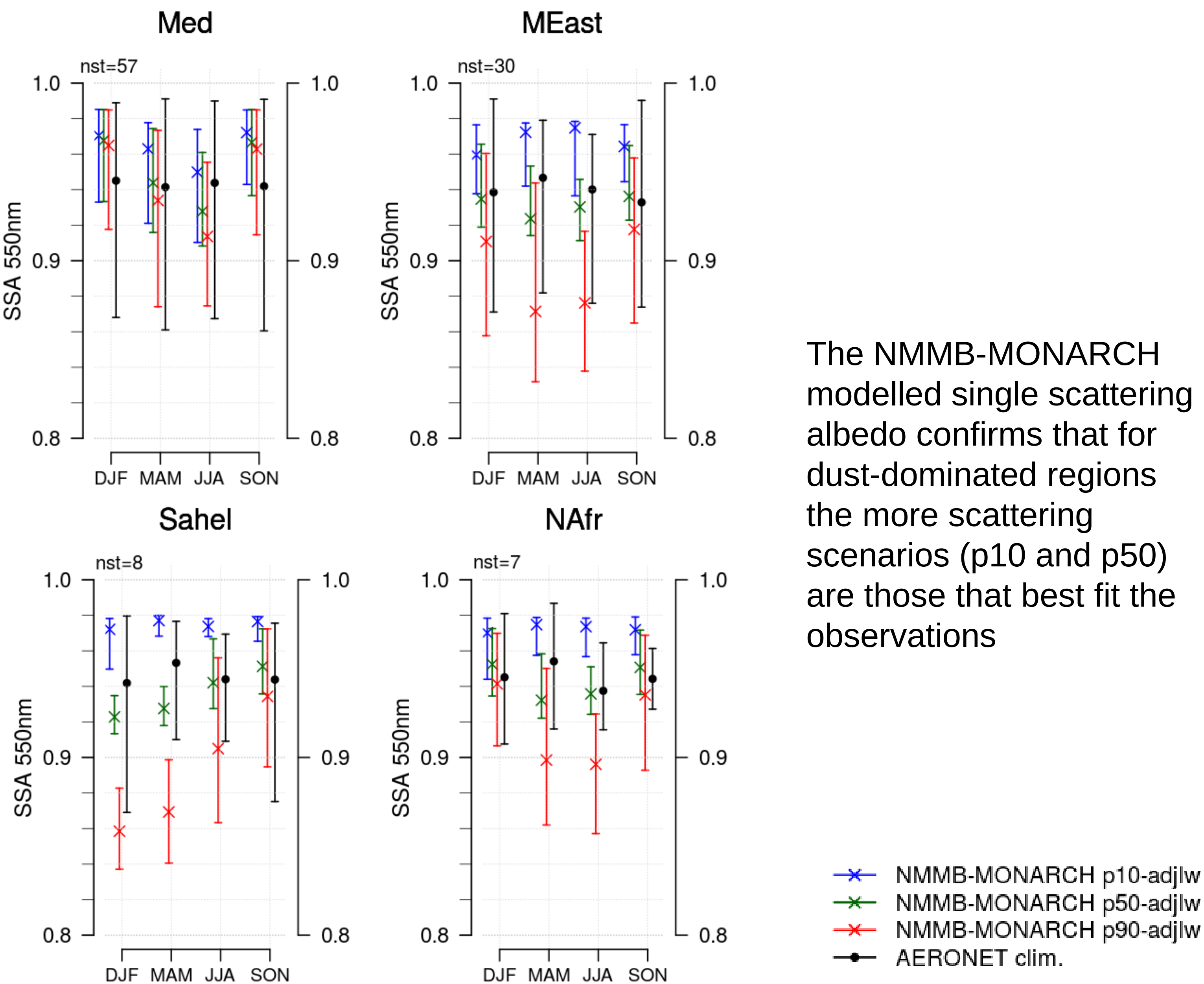

The seasonal dust optical depth at 550 nm is well captured by NMMB-MONARCH


Back to scenarios definition

Back to method for evaluation



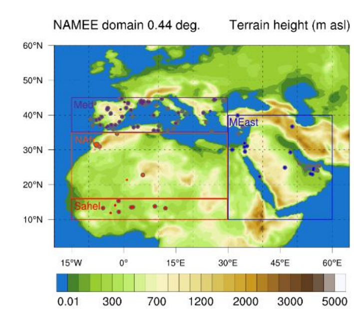
# Evaluation of SSA@550nm against AERONET data



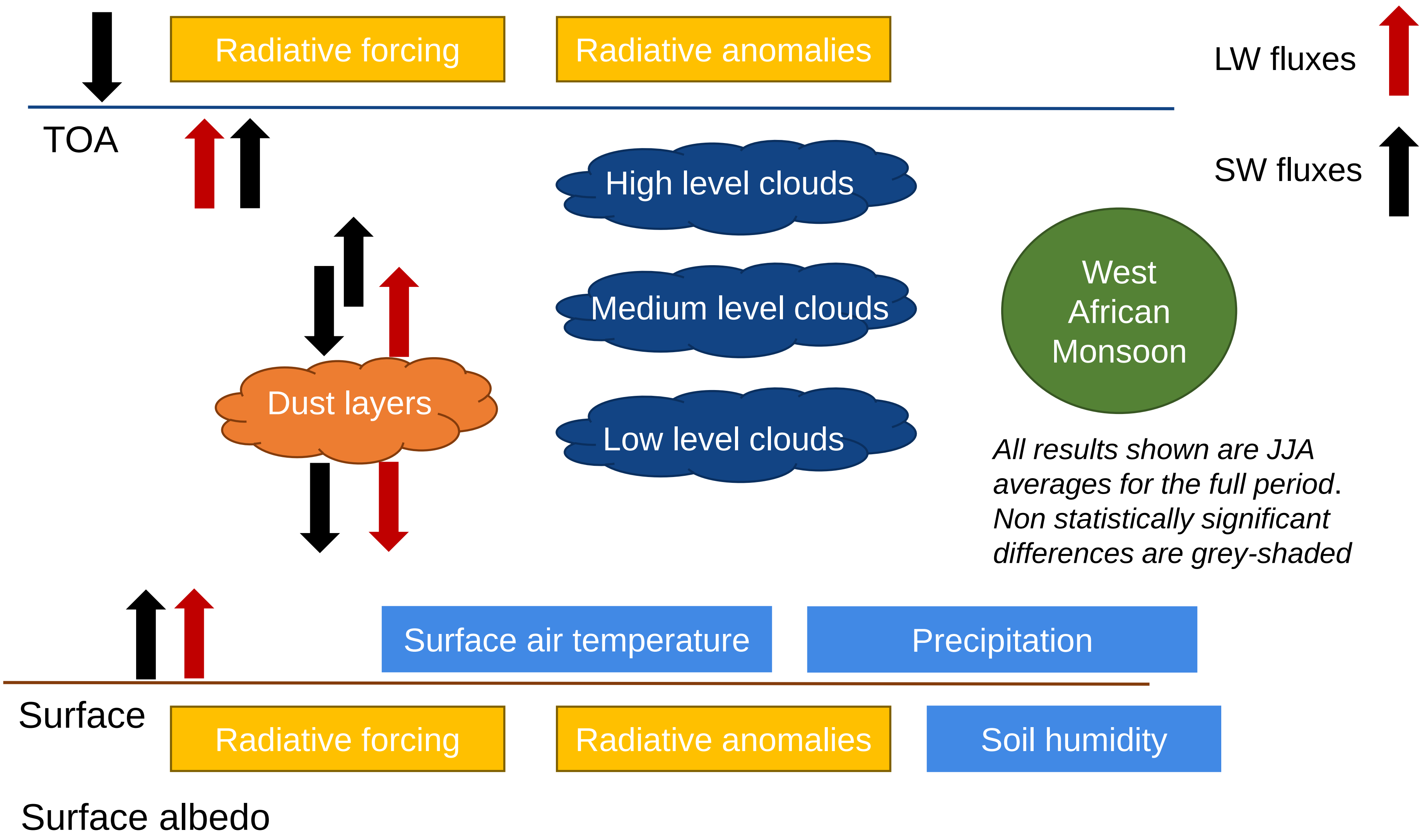

The NMMB-MONARCH modelled single scattering albedo confirms that for dust-dominated regions the more scattering scenarios (p10 and p50) are those that best fit the observations

Back to scenarios definition

Back to method for evaluation



# Regional climate responses (click in for details)

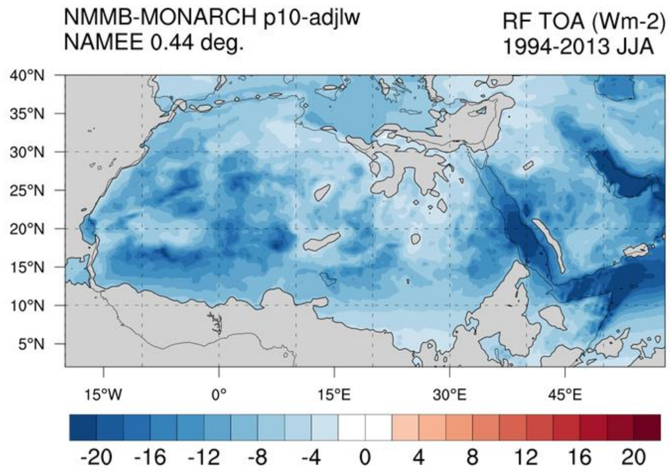


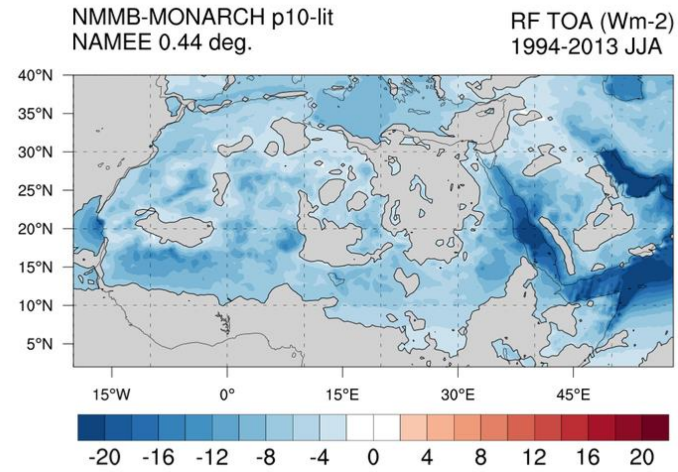

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

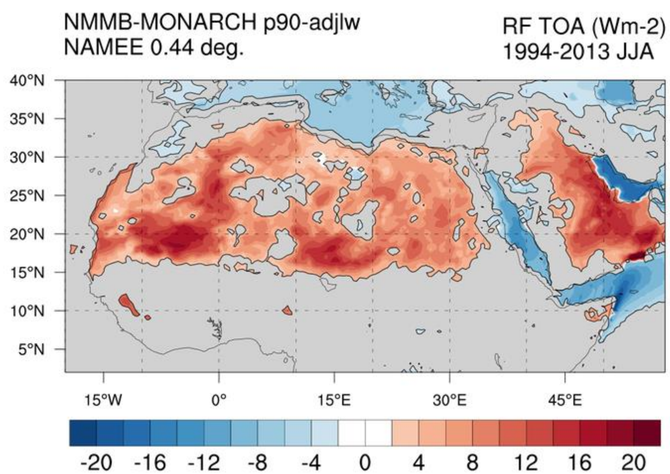
# Radiative forcing at TOA ($Wm^{-2}$)

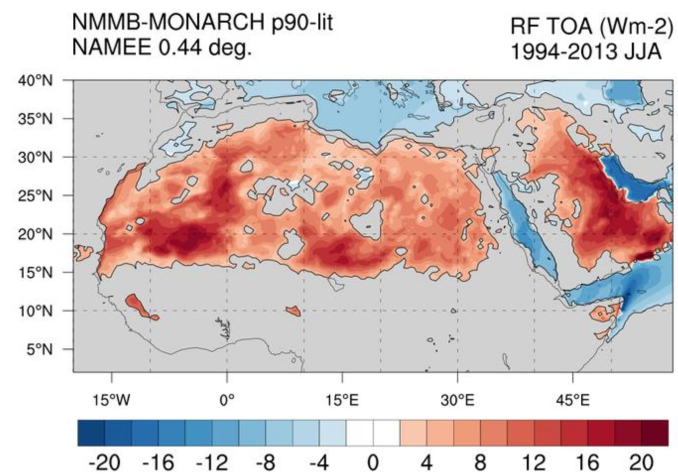
*sca*




*abs*




Back to scenarios definition

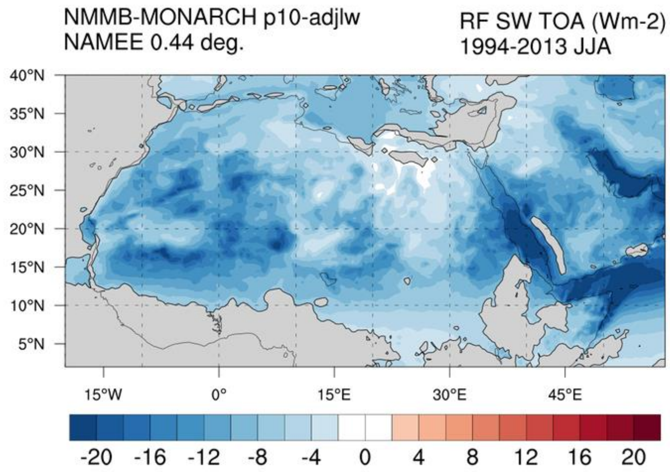
Back to climate responses map

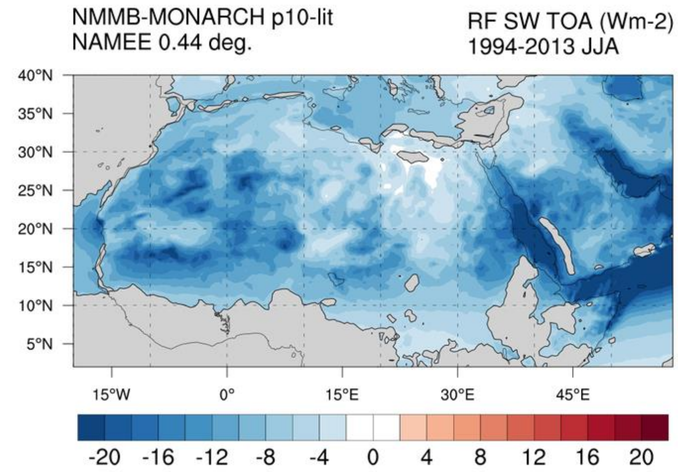
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

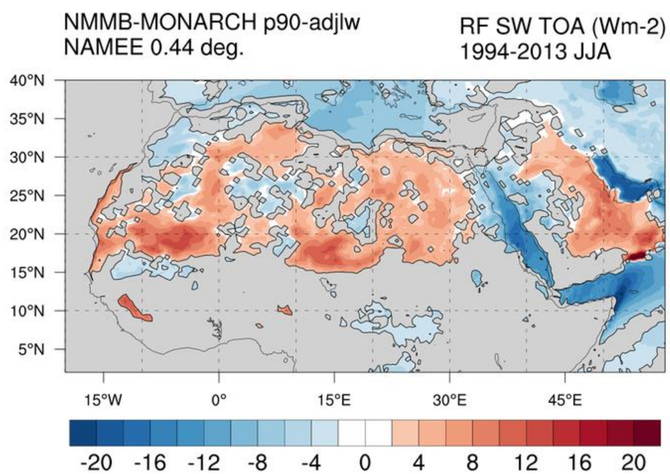
# SW radiative forcing at TOA ($Wm^{-2}$)

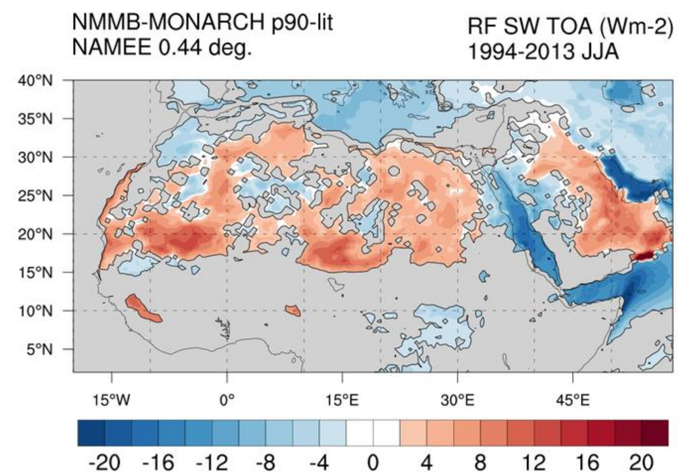
*sca*




*abs*




Back to scenarios definition

Back to climate responses map

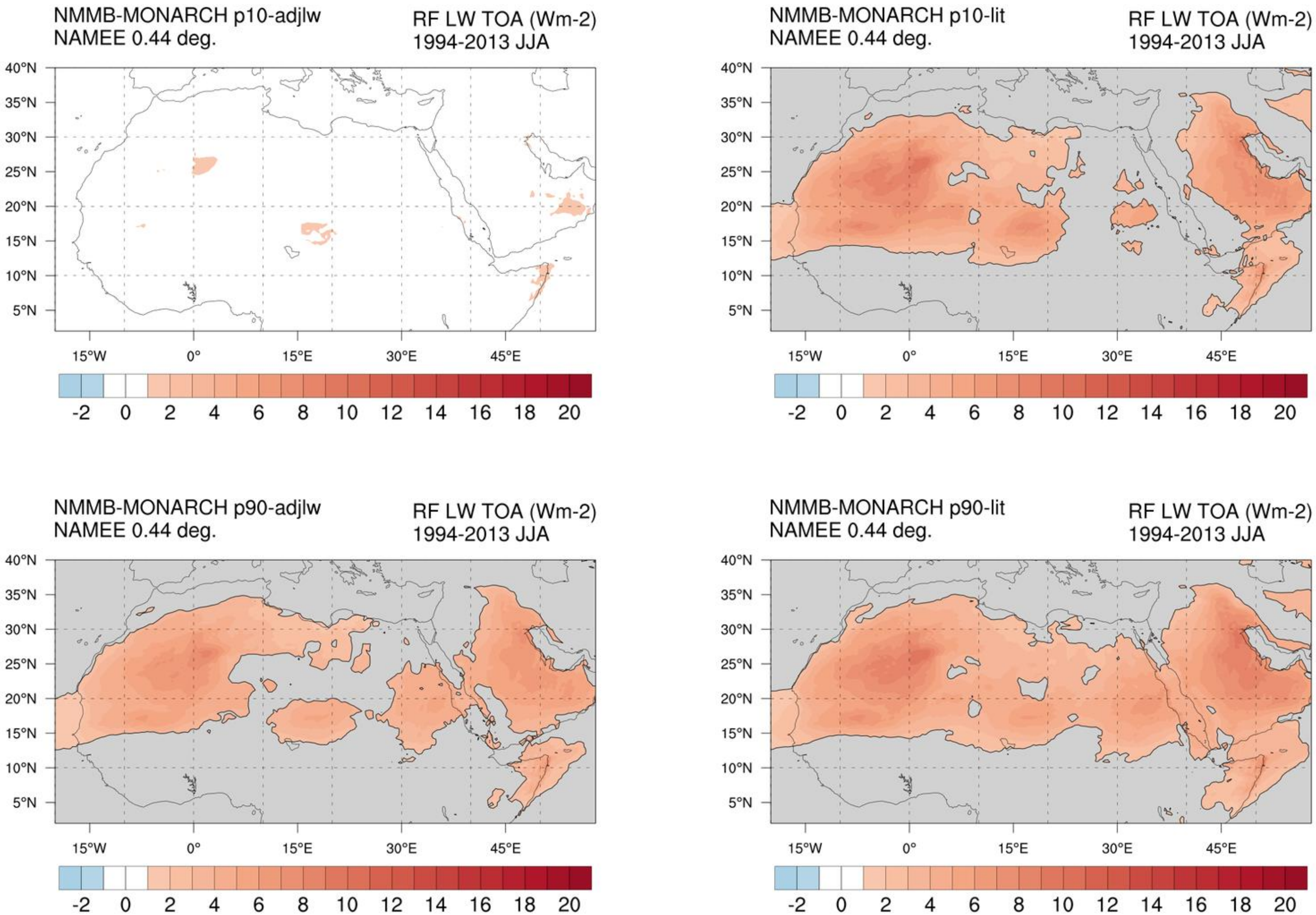
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# LW radiative forcing at TOA ($Wm^{-2}$)

*sca*

*abs*



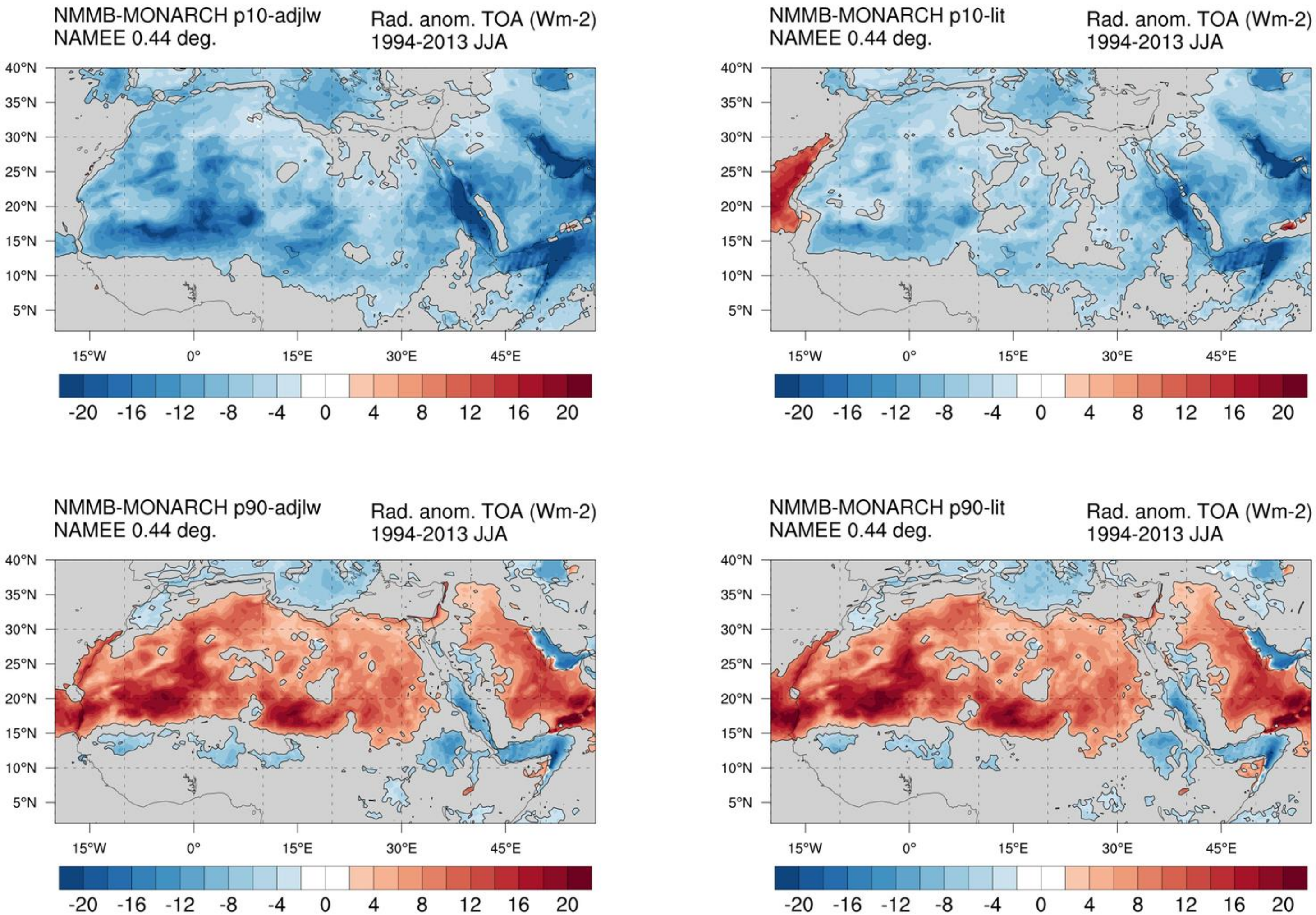

Back to scenarios definition

Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Radiative anomalies at TOA: cloud+aerosol (Wm$^{-2}$)




*sca*

*abs*

Back to scenarios definition

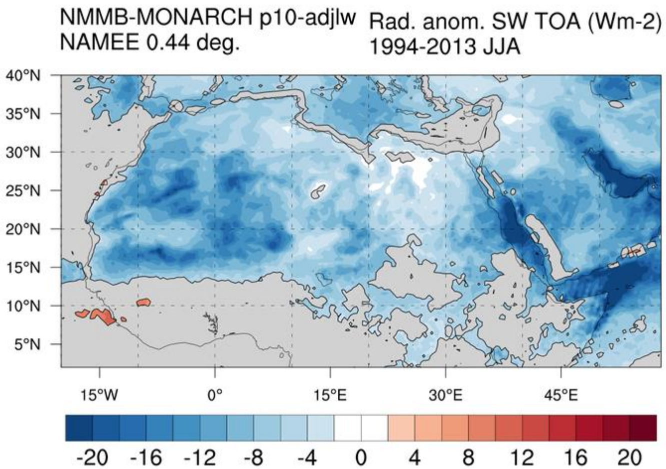
Back to climate responses map

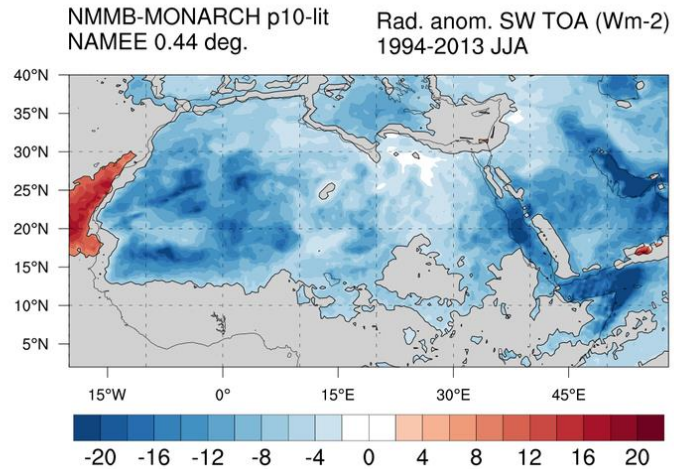
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

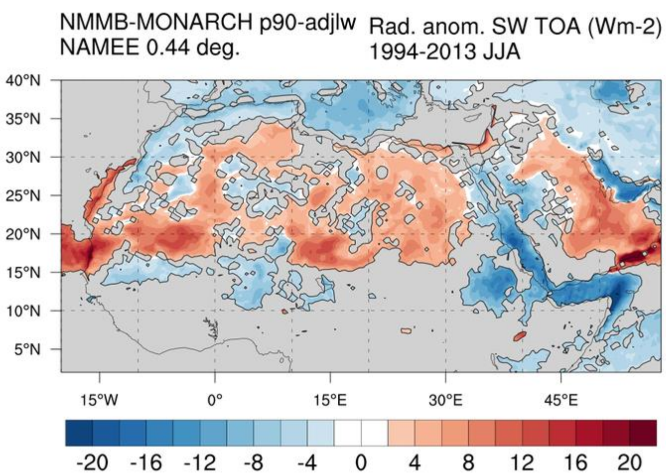
# SW radiative anomalies at TOA: cloud + aerosol ($Wm^{-2}$)

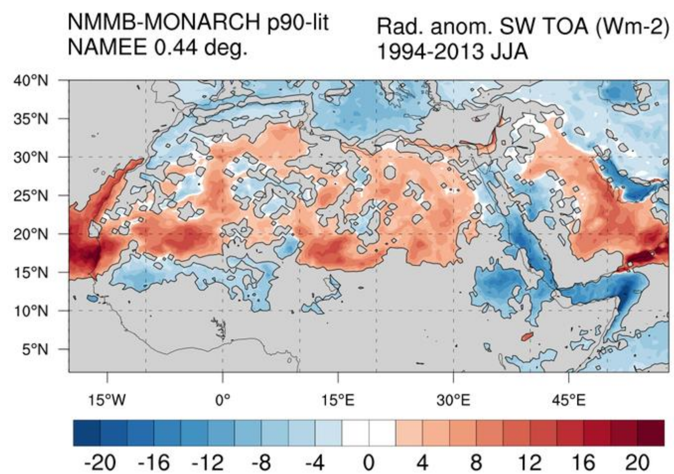
*sca*




*abs*




Back to scenarios definition

Back to climate responses map

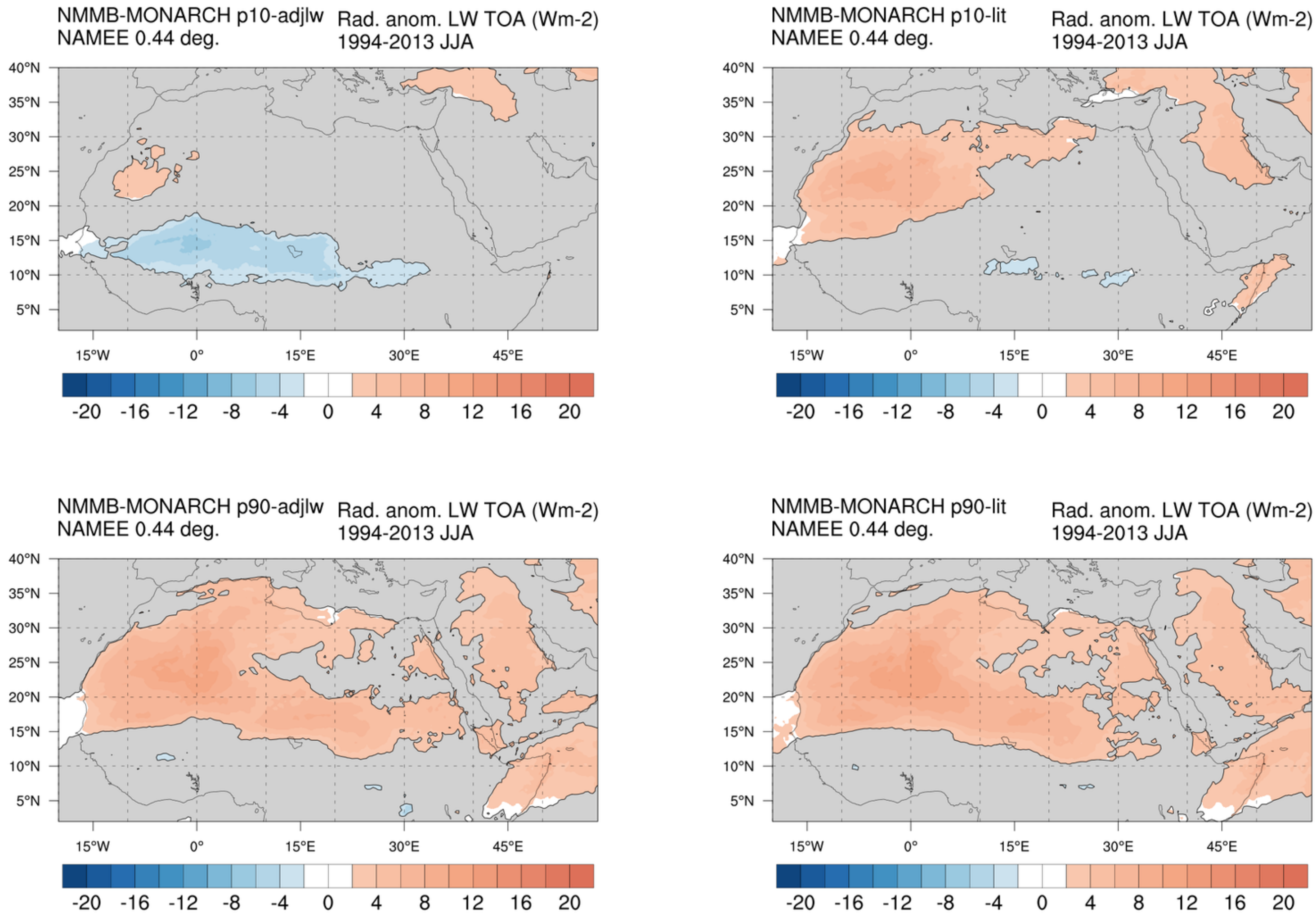
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# LW radiative anomalies at TOA: cloud + aerosol ($Wm^{-2}$)

*sca*

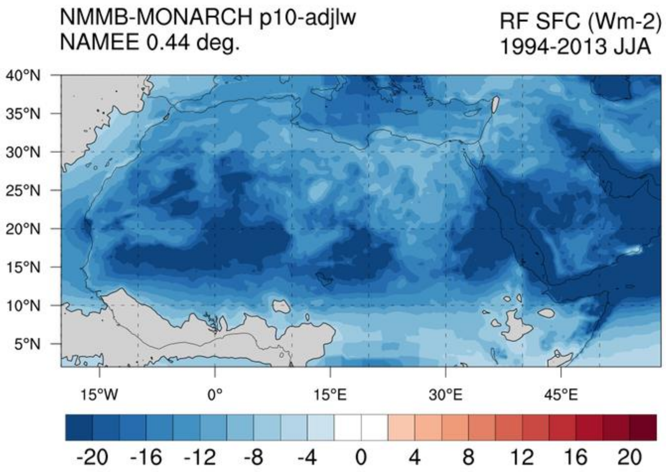
*abs*

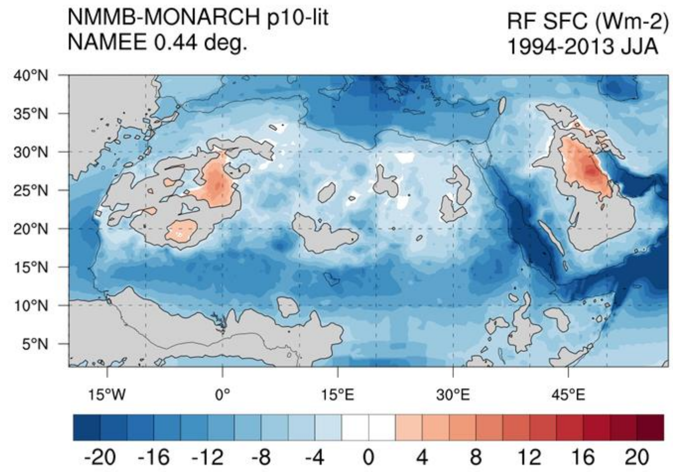



Back to scenarios definition

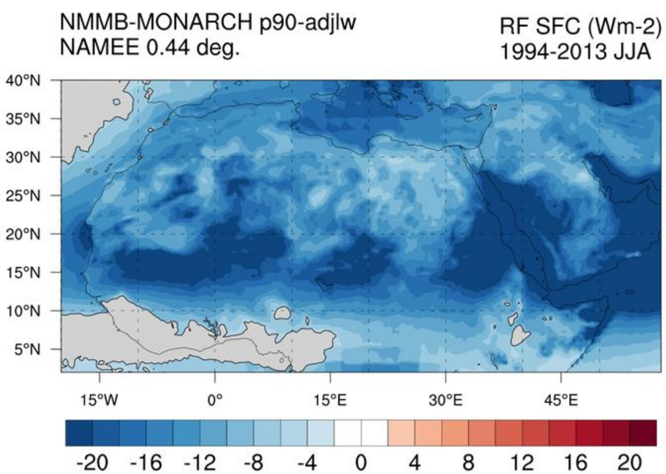
Back to climate responses map

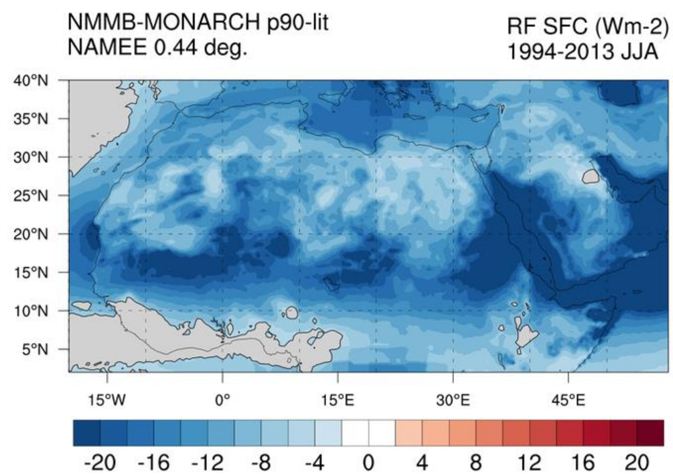
# Radiative forcing at surface ($Wm^{-2}$)




*sca*



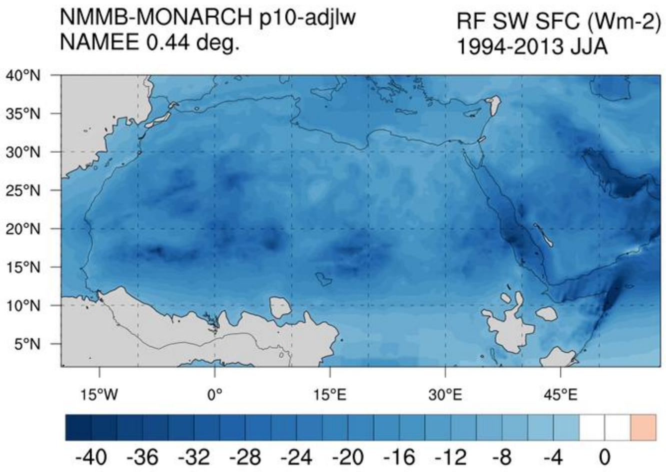

*abs*

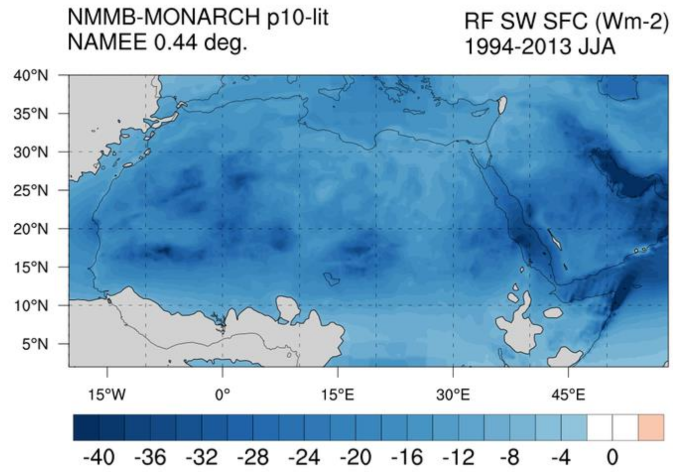
Back to scenarios definition

Back to climate responses map

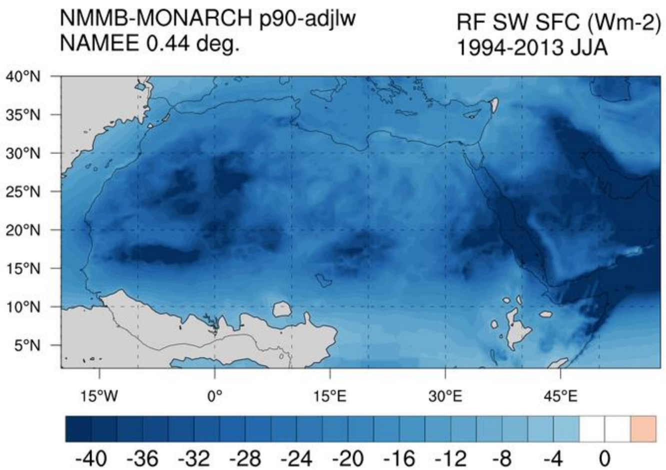
# SW radiative forcing at surface ($Wm^{-2}$)

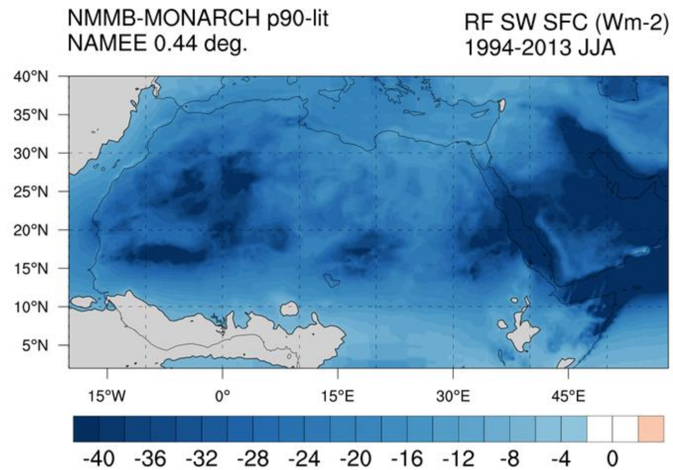
*sca*




*abs*

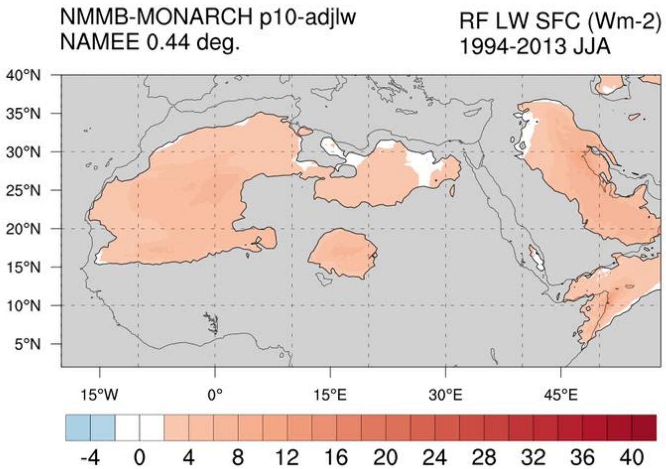


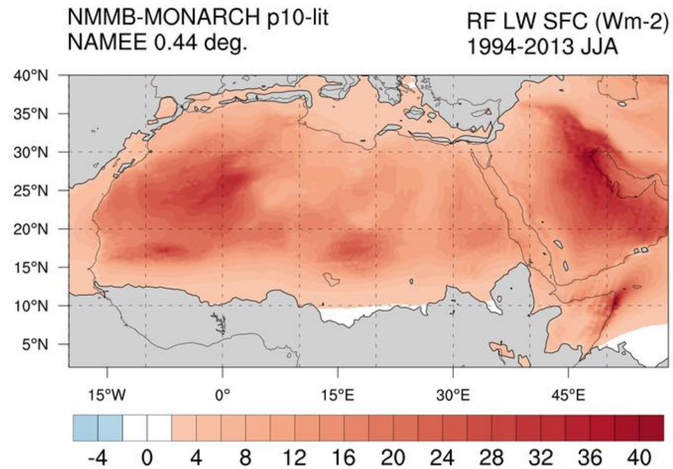




Back to scenarios definition

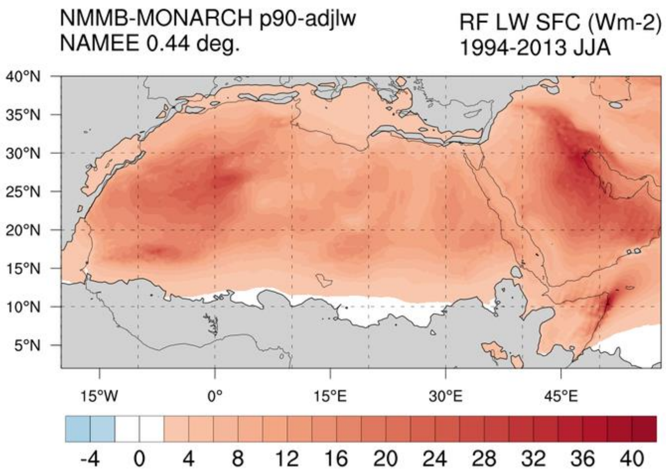
Back to climate responses map

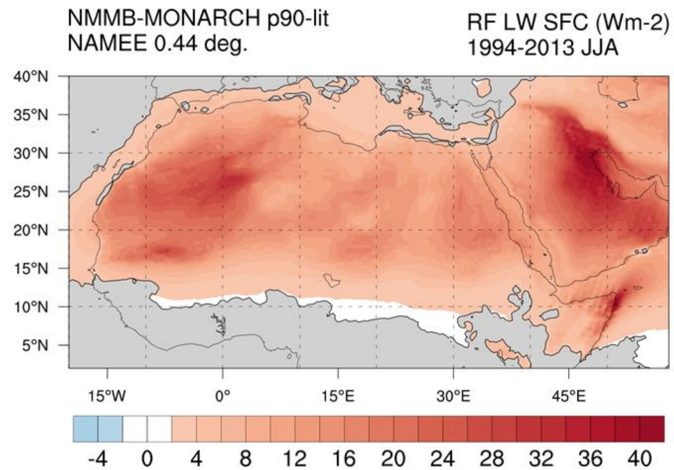
# LW radiative forcing at surface ($Wm^{-2}$)




*sca*



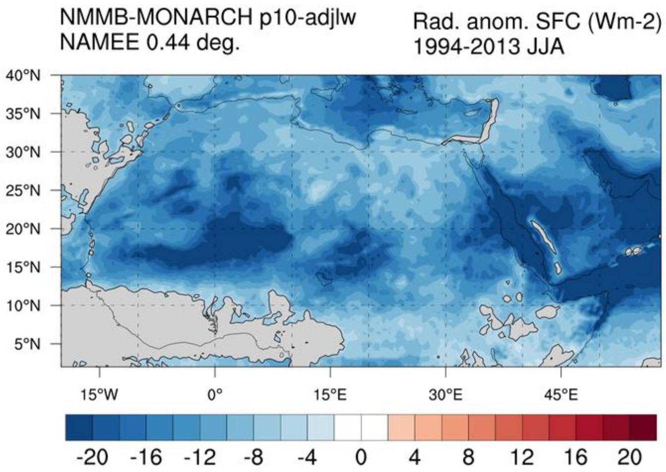

*abs*

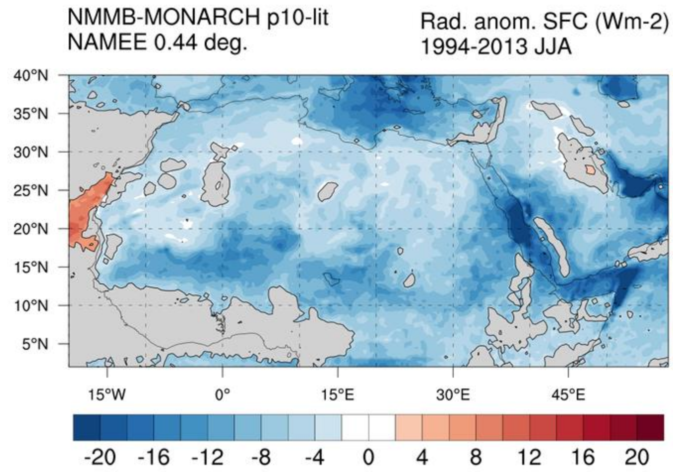
Back to scenarios definition

Back to climate responses map

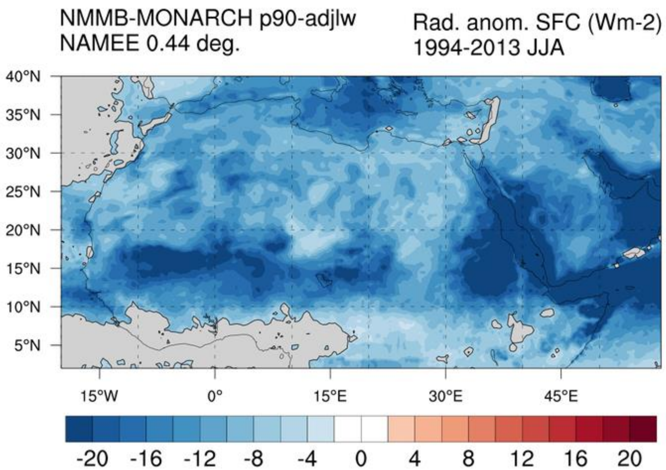
# Radiative anomalies at surface: cloud + aerosol ($Wm^{-2}$)

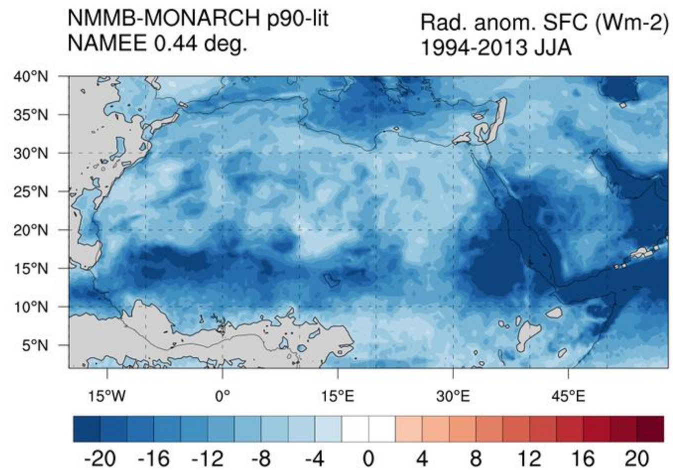
*sca*




*abs*




Back to scenarios definition

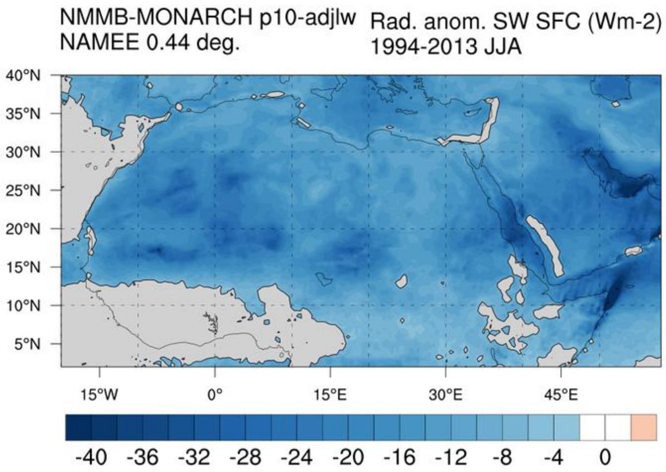
Back to climate responses map

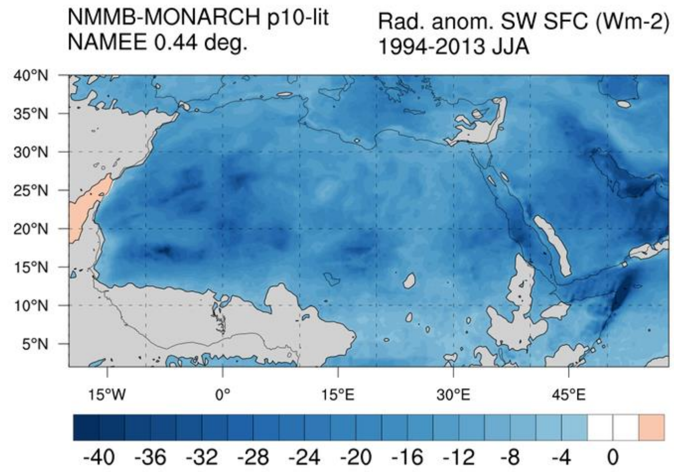
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

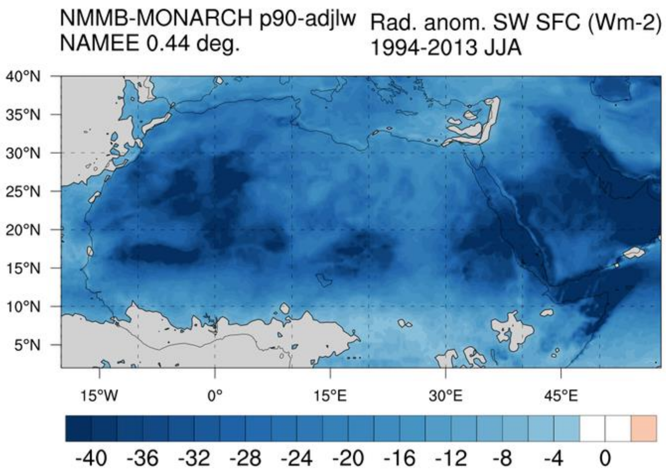
# SW radiative anomalies at SFC: cloud + aerosol ($Wm^{-2}$)

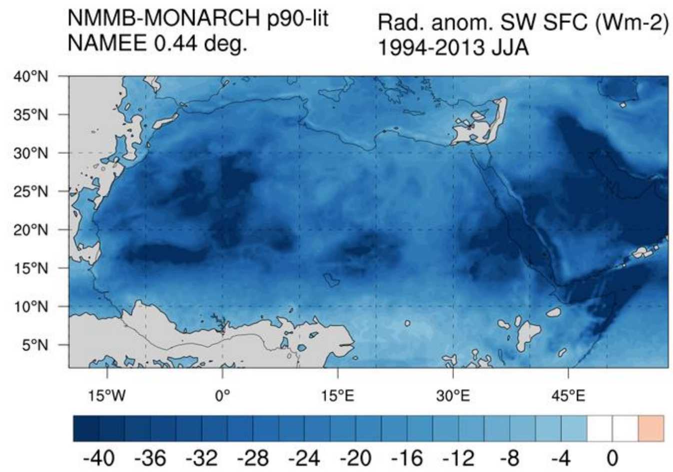
*sca*




*abs*




Back to scenarios definition

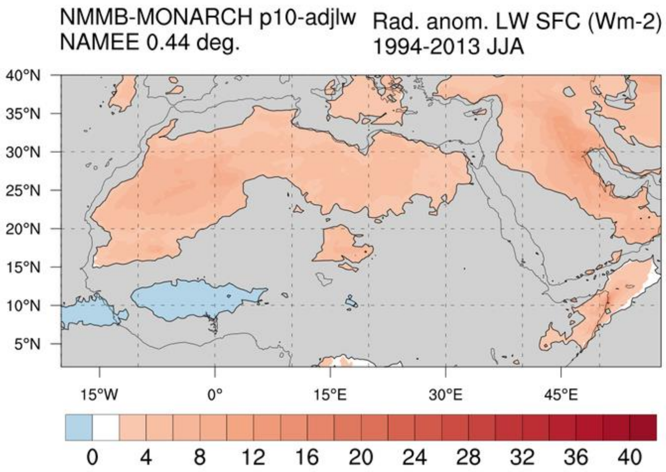
Back to climate responses map

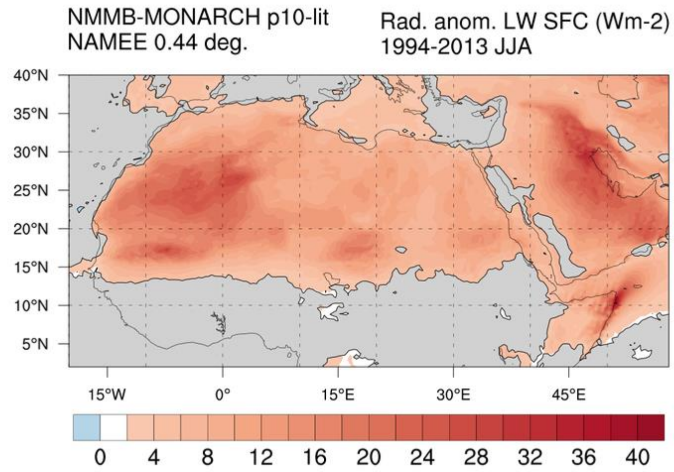
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

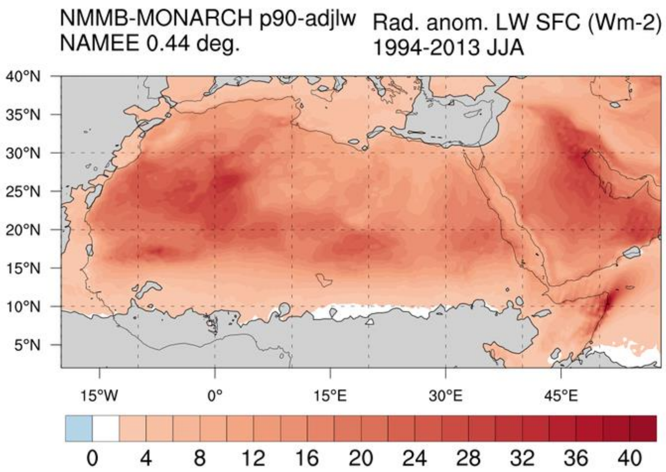
# LW radiative anomalies at SFC: cloud + aerosol ($Wm^{-2}$)

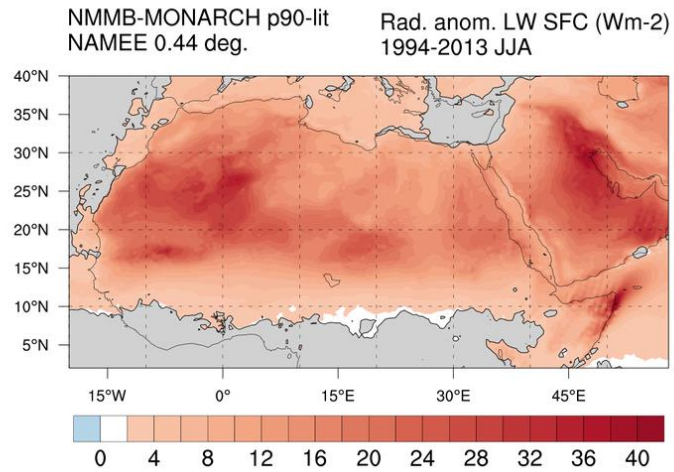
*sca*




*abs*



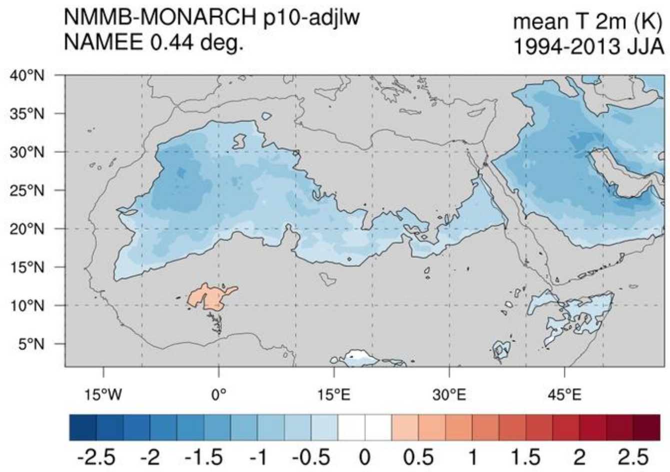

Back to scenarios definition

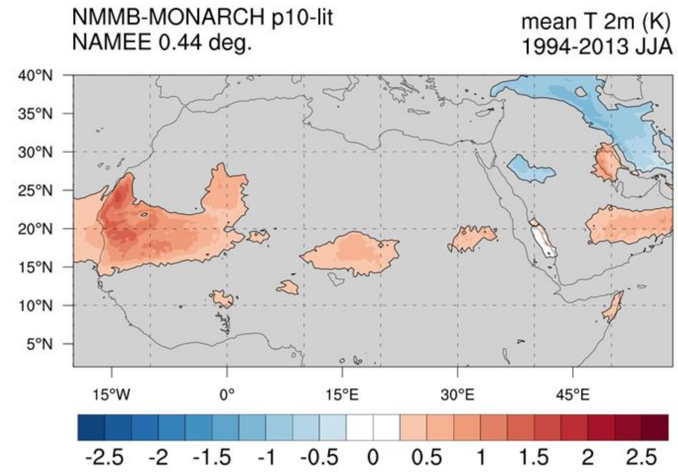
Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

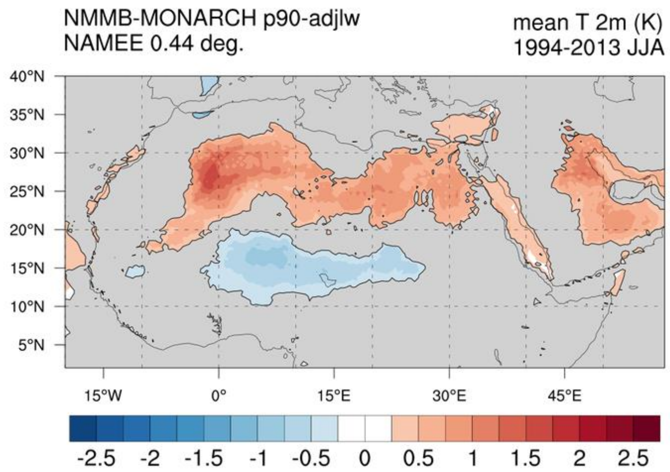
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

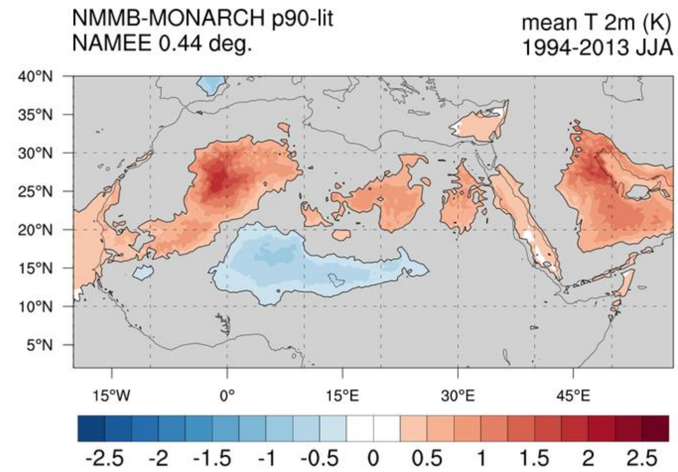
# Daily mean temperature at 2 m (K)




*sca*




*abs*

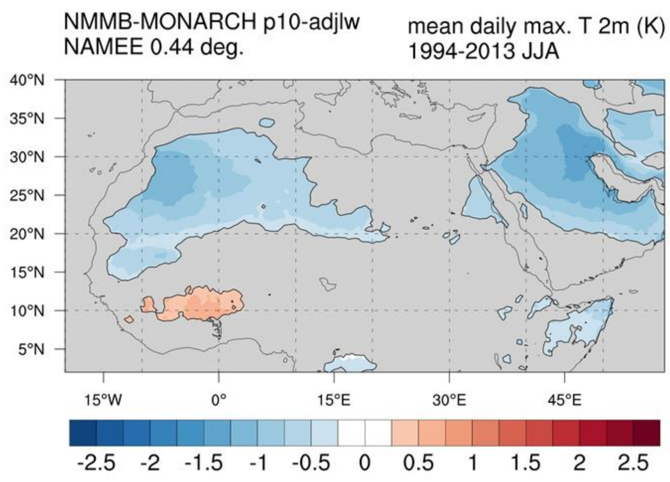
Back to scenarios definition

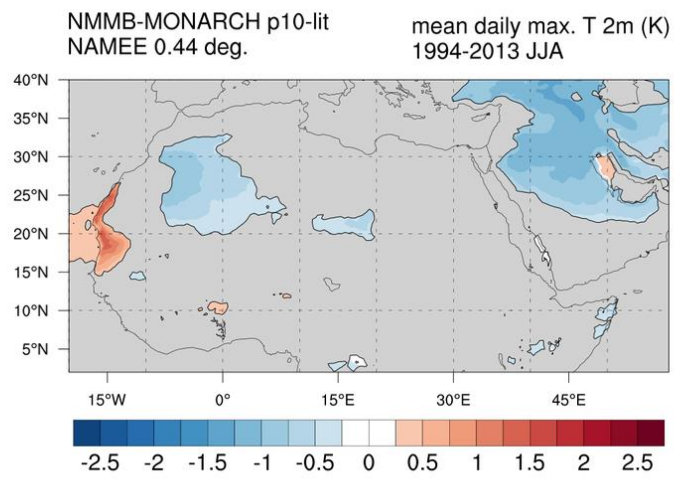
Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

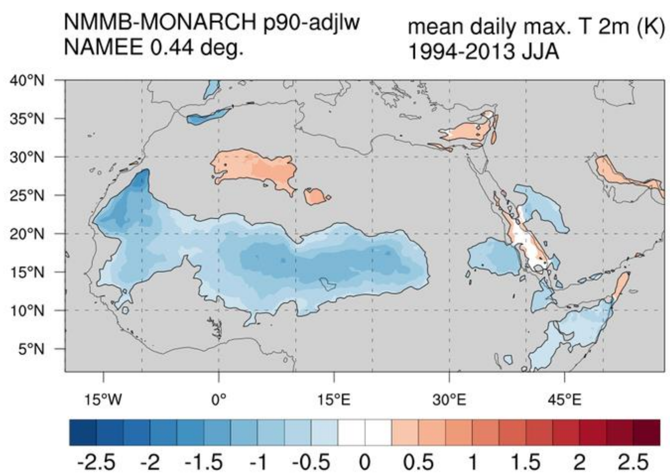
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

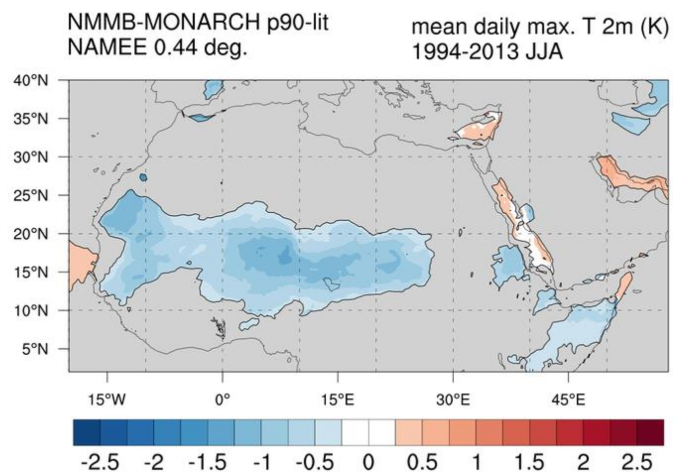
# Maximum daily mean temperature at 2 m (K)




*sca*



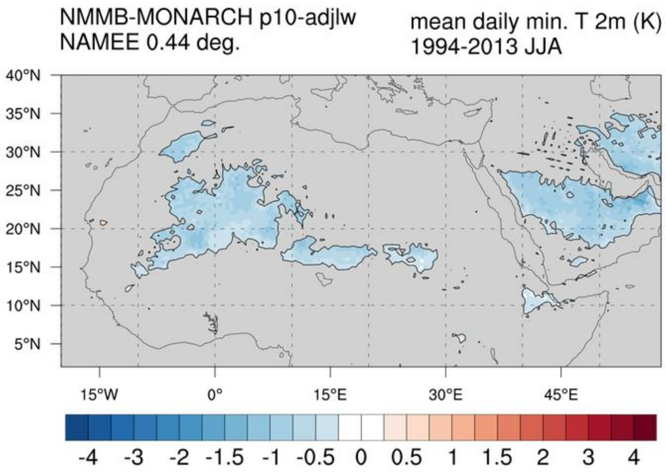

*abs*

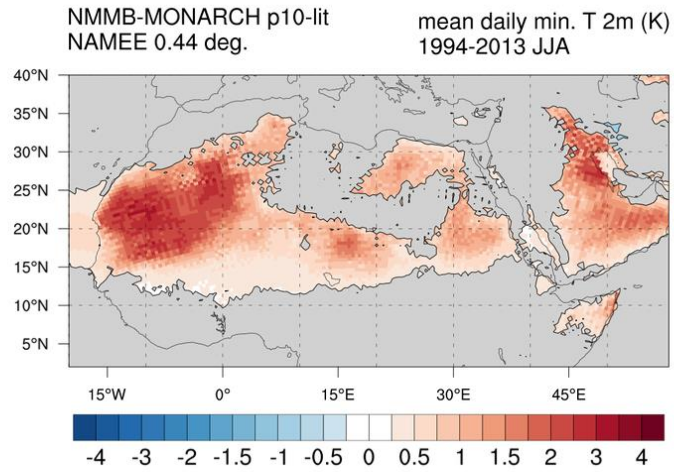
Back to scenarios definition

Back to climate responses map

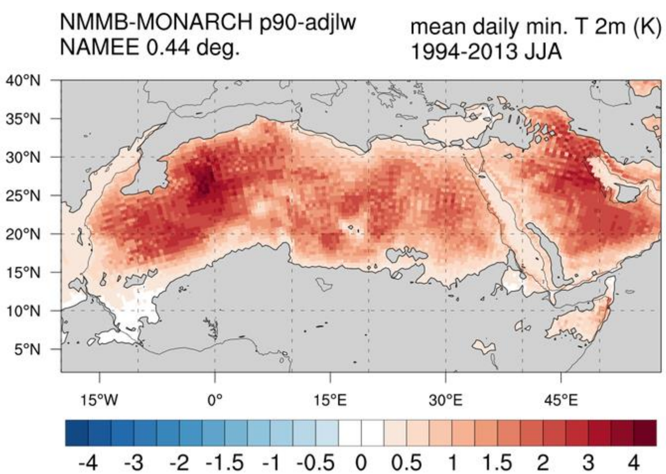
# Minimum daily mean temperature at 2 m (K)

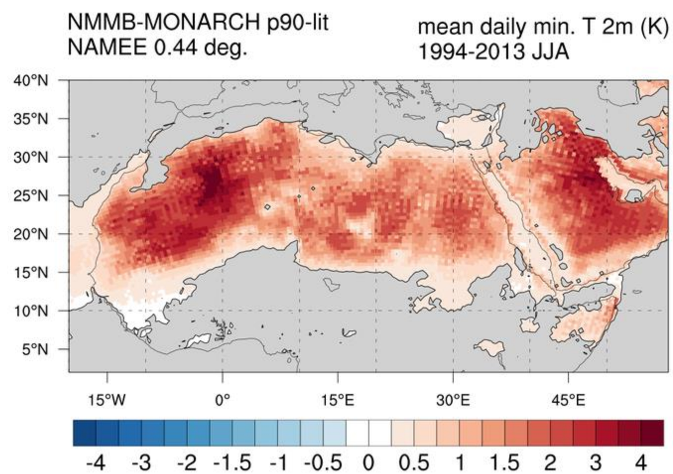
*sca*




*abs*




Back to scenarios definition

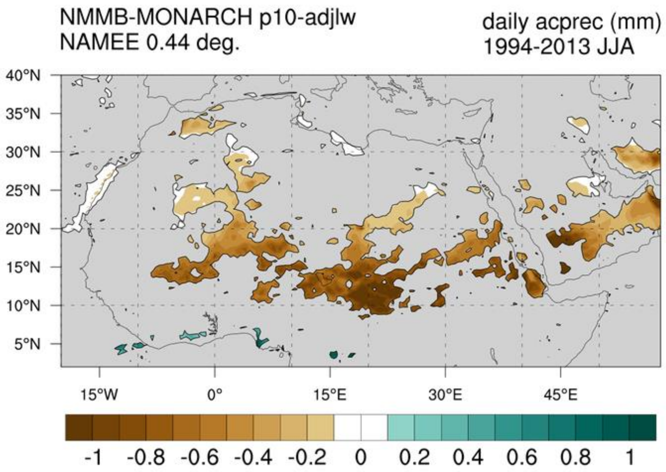
Back to climate responses map

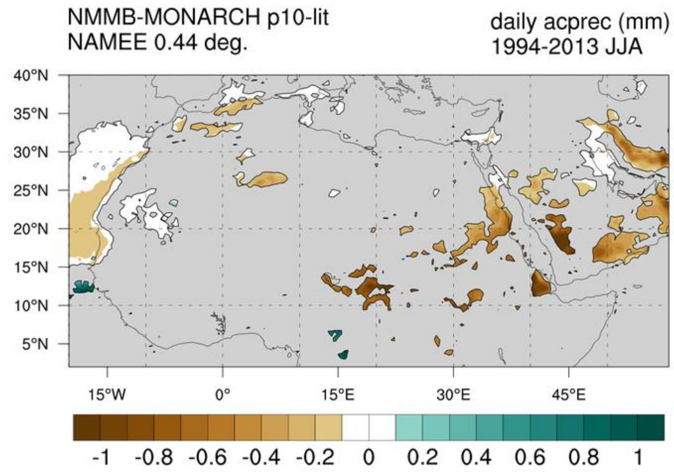
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

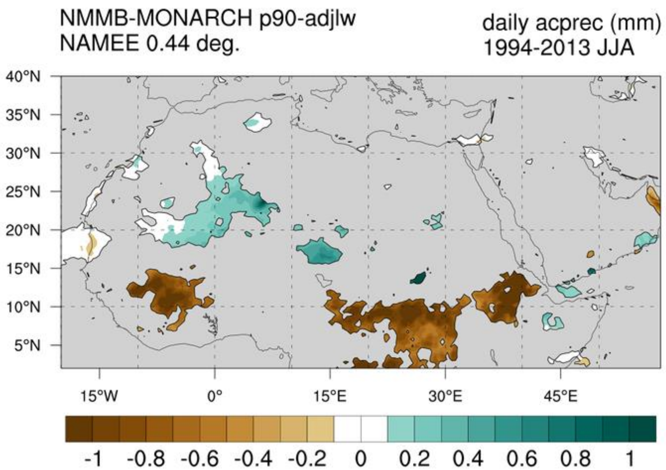
# Daily accumulated precipitation (mm/day)

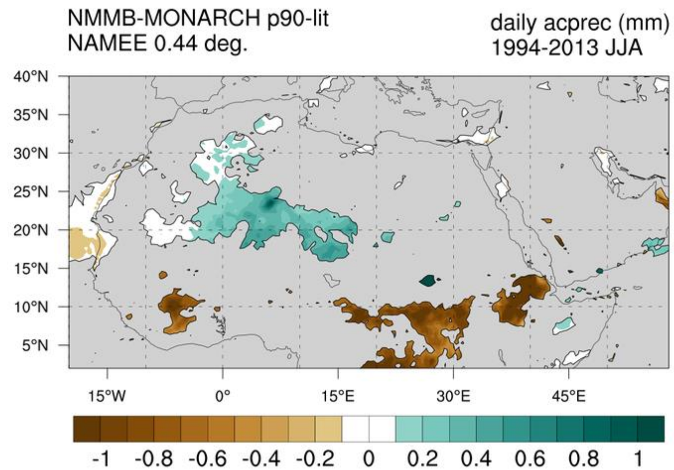
*sca*




*abs*



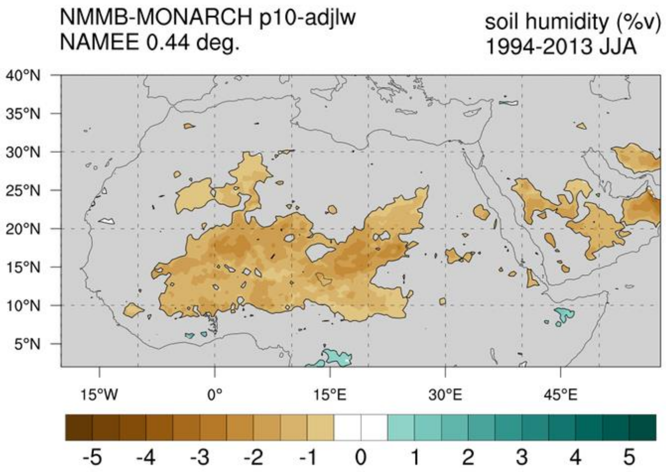

Back to scenarios definition

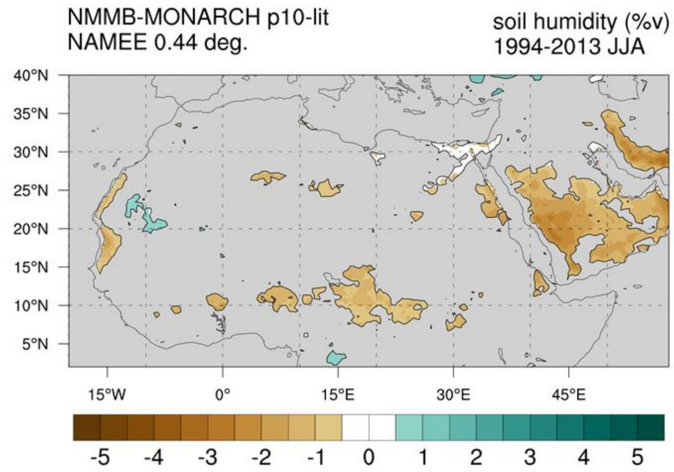
Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

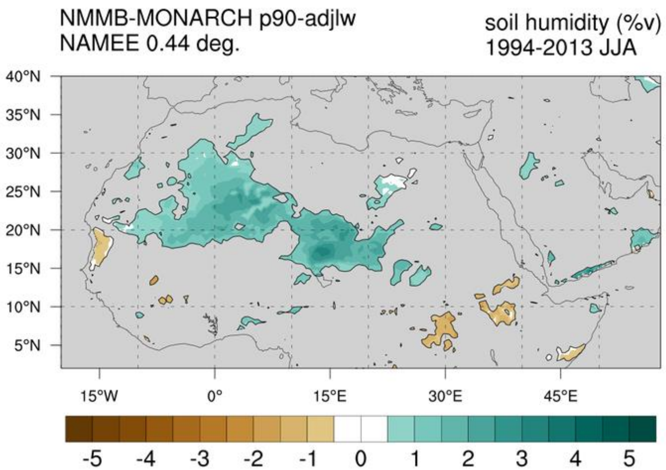
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

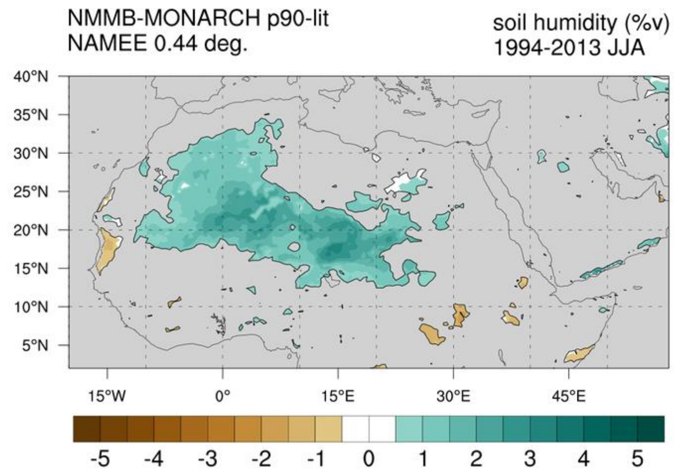
# Soil humidity (%v)




*sca*



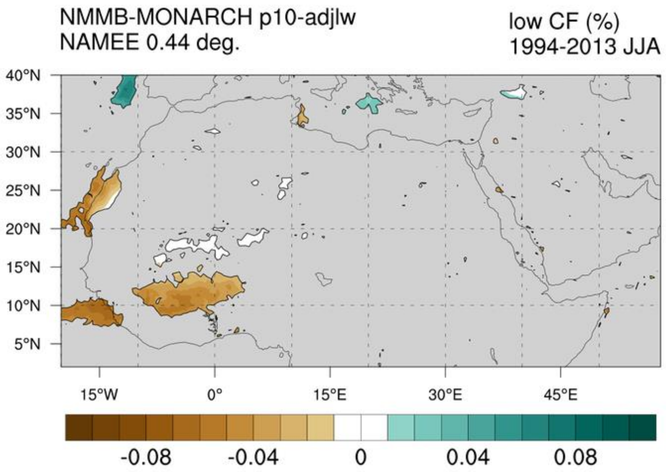

*abs*

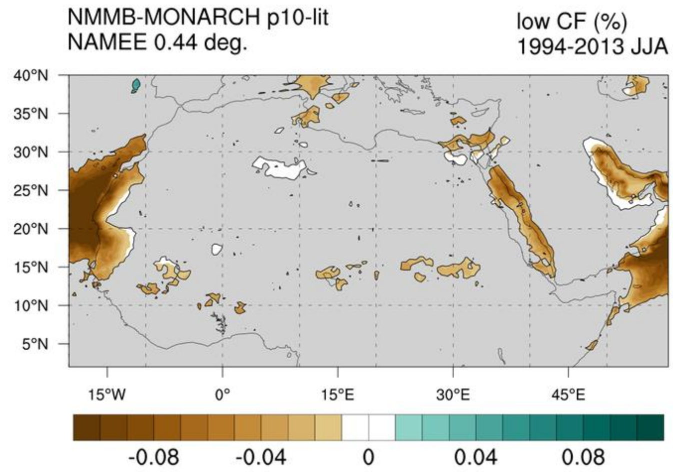
Back to scenarios definition

Back to climate responses map

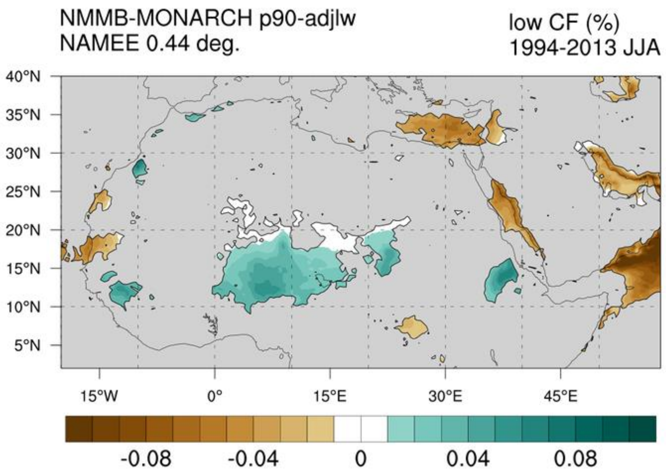
# Low level cloud fraction (%)

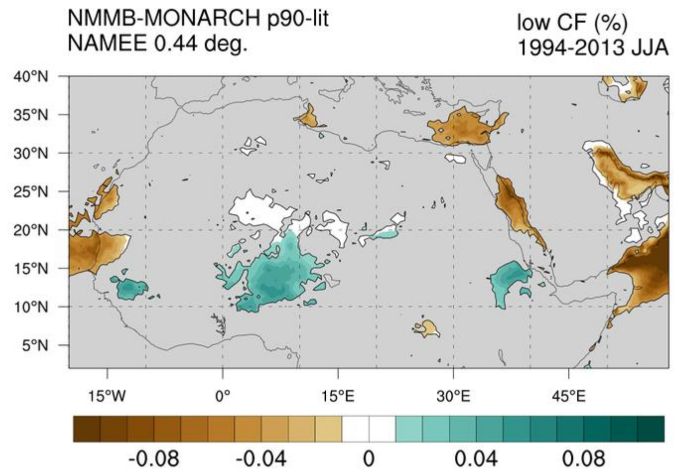
*sca*




*abs*



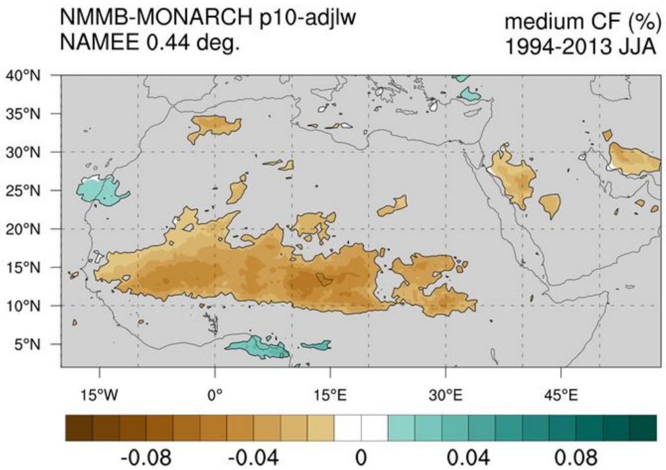

Back to scenarios definition

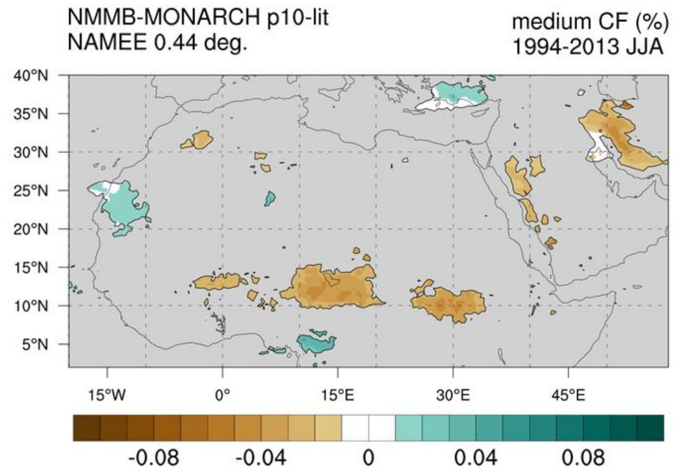
Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

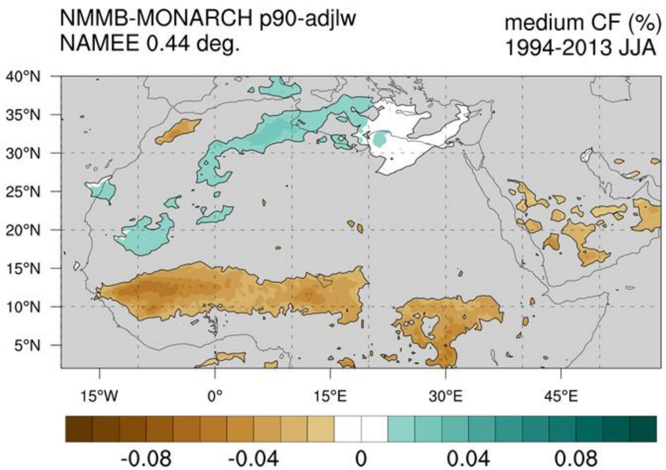
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

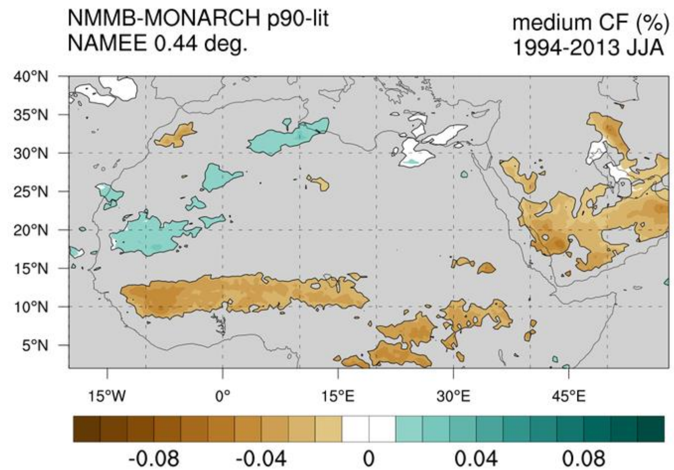
# Medium level cloud fraction (%)




*sca*




*abs*

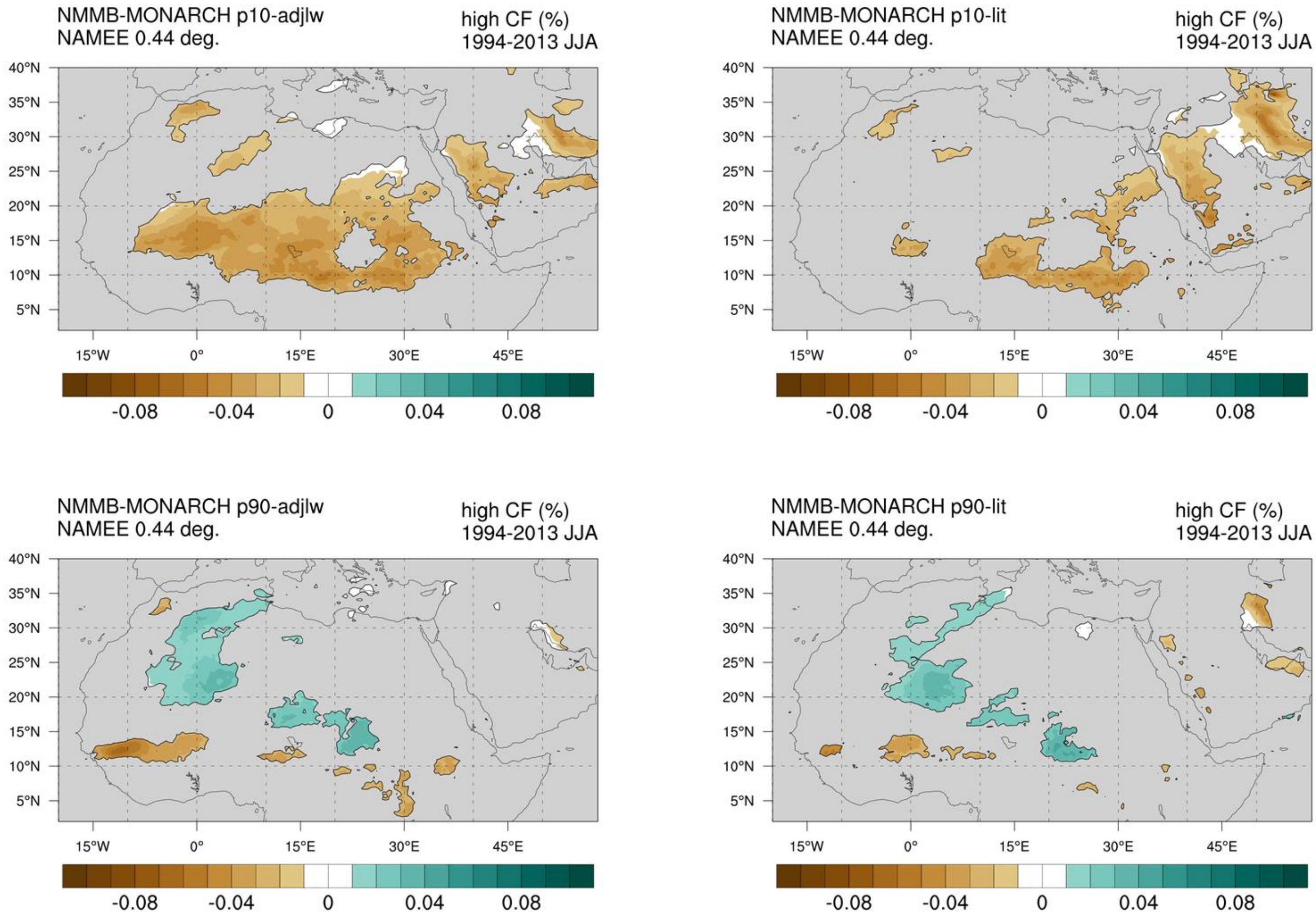
Back to scenarios definition

Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# High level cloud fraction (%)




*sca*

*abs*

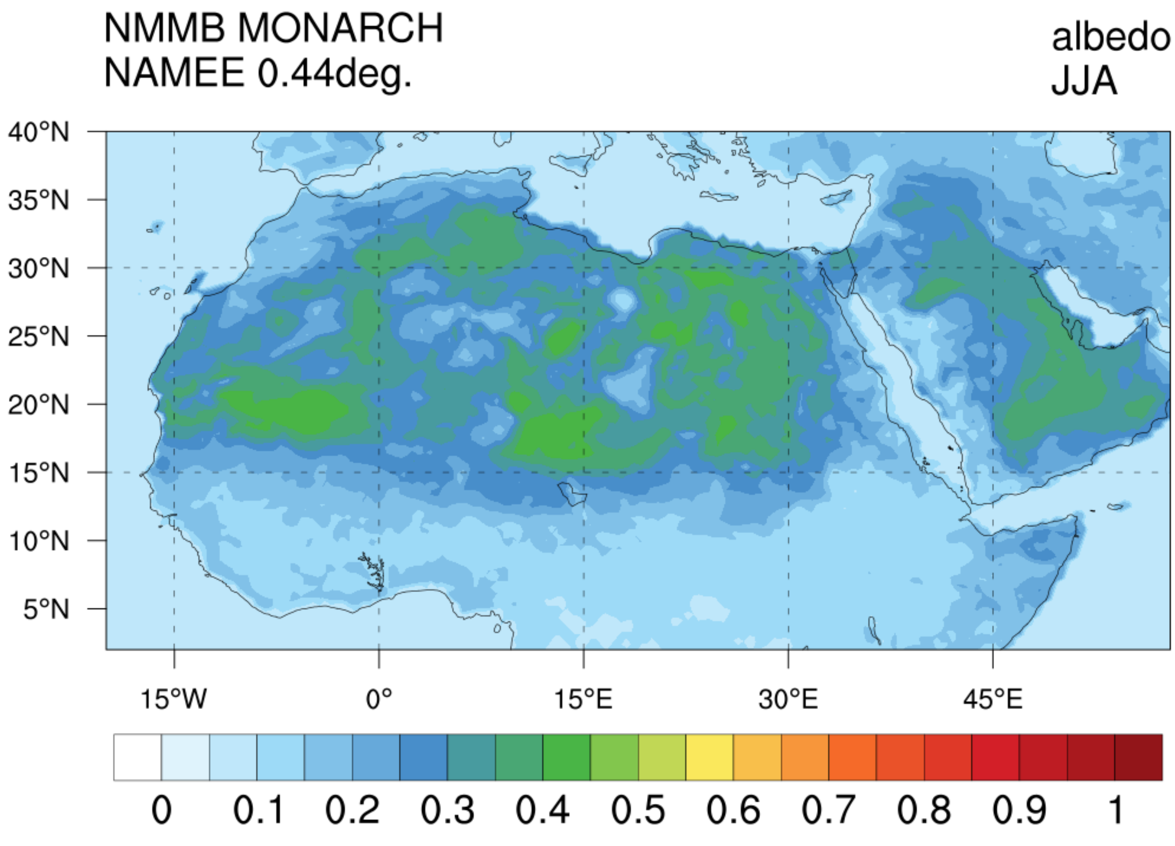
Back to scenarios definition

Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Climatological surface albedo




Back to scenarios definition

Back to climate responses map

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering

# Conclusions

- Modelling of dust optical properties from literature refractive indexes for minerals falls within the observed ranges for the SW
- Discrepancies between the modelled imaginary part of the refractive indexes and chamber derived values arise in the LW (particularly in the quartz-clays absorption band)
- The range of variability produced by our optical modelling derives in opposite climate responses over North Africa, particularly during the Monsoon season (JJA) with:
  - positive (negative) forcing at TOA,
  - increase (decrease) of surface air temperature,
  - increase (decrease) of precipitation,

  for our absorbing (p90) and scattering (p10) scenarios
- Climate responses, i.e. LW fluxes and minimum daily temperature, are sensitive to the differences in the LW derived from literature-retrieved and chamber observed refractive indexes

# Acknowledgments


- The authors would like to thank **Claudia Di Biagio, Paola Formenti**, and their coauthors who kindly provided their chamber measurements (Di Biagio et al., 2017; 2019) to be used in our simulations.
- Thanks also to **M. Schulz** and the researchers of the **Division for Climate Modelling and Air Pollution** of the **MetNO**, for the fruitful discussions in the early stages of this work.
- We acknowledge the **AERONET** network, the **European Center for Medium-Range Weather Forecasts**, and the research groups that contribute to them, who openly share their data.
- Thanks to **the Earth Observation Data group** of the Department of Physics (Oxford University) for compiling and publishing the Aerosol Refractive Index Archive (ARIA)
- We thankfully acknowledge the computer resources at ***Marenostrum*** and the technical support provided by the **Barcelona Supercomputing Center** and the **CES team** of the Earth Sciences Department.
- This work counts on the support of the **FRAGMENT** ERC and the **AXA Chair on Sand and Dust Storms**, both led by Dr. Carlos Pérez García Pando.


- NMMB-MONARCH references:

Janjic, 2003; Janjic et al., 2011; Pérez et al., 2011; Haustein et al., 2012; Jorba et al., 2012; Spada et al, 2013; Badia and Jorba, 2014; Badia et al., 2017; Di Tomaso et al, 2017

- References to model configuration:

RRTM SW and LW radiation (Iacono et al., 2001, 2008). Betts-Miller-Janjic convection scheme (Betts, 1986; Betts and Miller, 1986; Janjic, 1994). Ferrier microphysics (Ferrier et al., 2002). Mellor-Yamada-Janjic turbulence (Janjic, 2002; Mellor and Yamada, 1982). Noah land surface model (Ek et al., 2003). GOCART climatology (Chin et al. 2002).

Open positions in our group

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Project and Construction Engineering